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THE RECOVERY OF GAS WORKS BY-PRODUCTS.*

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THE term "by-product" may, I think, best be defined in the words of a well-known writer on the subject, Professor Chas. E. Munroe, who refers to such materials as "substances or results obtained in the operation of a specific process in addition to the substance or result primarily sought."

The foregoing definition is much to be preferred to the commonly accepted one wherein they are referred to as "secondary products," for no reference is here made either directly or implied to their commercial value or importance, and instances may be recalled where the primary product finally became of secondary importance to a by-product, which in the early stages of the operation was considered to be of little or no value.

It is but natural, therefore, that investigations having as their object the recovery and utilization of by-products in any field of industrial endeavor, are apt to prove interesting, if not always profitable. This is particularly true of gas works by-products, owing to the fact that some of the most important and useful substances employed in medicine and the arts are derived from residuals produced in connection with the manufacture of illum-

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inating gas. Some idea of the diverse character of these compounds can be gained from Figure 1.

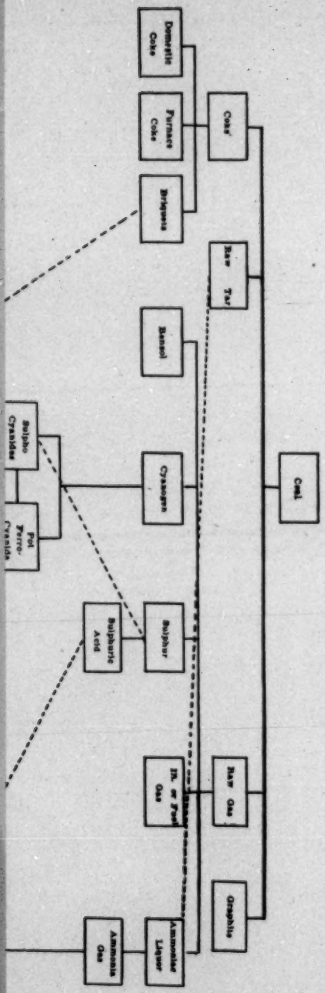
The volume and importance of these so-called gas works residuals is such, that their refinement and exploitation have given birth to new industries, producing in their turn primary products with the usual accompaniment of secondary by-products; and it perhaps may be truly said that there is hardly a branch of chemical manufacture that does not require and use some chemical having its origin in by-products from the destructive distillation of coal or oil either in the process of the manufacture of illuminating gas or in modern by-product coke ovens having, generally, as their primary object the manufacture of metallurgical coke.

Much has been written upon this class of materials, and it would be unwise and perhaps tiresome to you to attempt more than a brief review of the subject as a whole. I shall also confine my remarks to gas works by-products, as those produced in coke ovens are of quite similar composition; and, too, the early history and development of this industry is inseparably interwoven with the history and development of the illuminating gas industry.

The subject treated refers especially to tar, ammoniacal liquor, and coke, but other less important associated by-products will also be touched upon. The physical characteristics of these substances are well known to you and need no special description at the present time. The products derived from them will, however, be considered, following a brief historical review of the status of these materials in relation to the gas business and their method of recovery in a modern gas plant.

Historical.

Although it was early recognized by Winsor (1803) and other gas engineers of his day, that coke, as a domestic fuel, was of equal or nearly equal value as the gas; tar and ammoniacal liquor represented at the start and for a number of years thereafter, an intolerable nuisance, and even as late as 1841, a description of an apparatus devised " for most effectually converting into carburetted hydrogen gas the tar and ammoniacal liquor produced from the coal in the retort as they, in a state of vapor, are on their passage to the hydraulic main " was considered of sufficient importance to be specially mentioned in the preface to a



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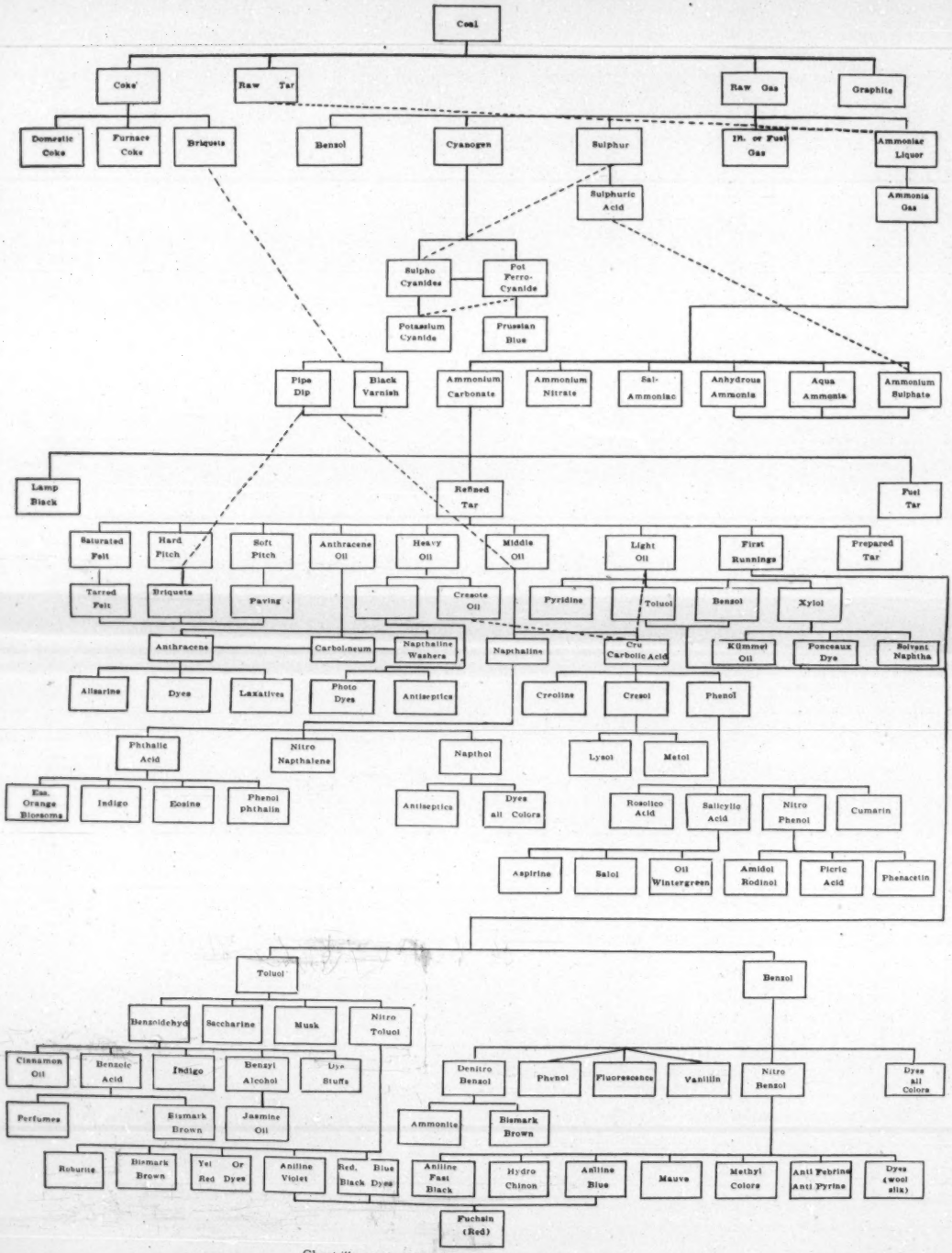

Chart illustrating the products and by-products of coal.

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treatise on "Gas Lighting" by a civil engineer of the day—Thomas S. Peckston—and to be dealt with at length in the volume cited.

The necessity for delivering to the consumer a gas free from such impurities as tar and ammonia, as well as for manufacturing and distribution reasons, made it imperative then, as it is to-day, that they be removed from the gas, whether or not they could be disposed of at a profit, it being out of the question to attempt to distribute gas containing more than a very minute trace of ammonia or tar. In the early days of the gas industry, therefore, the engineer was more concerned with the more or less complete removal of these impurities from the gas, than he was over the recovery of them in salable form.

Prior to the beginning of the Eighteenth Century, very little attention appears to have been given to the tar formed in connection with the heating of coal. It is of historical interest, however, to note a patent granted, in 1681, to Joachim, Becher and Searle, describing a "new way of making pitch and tarre out of pit coale never before found out or used by others." One of them, a German chemist, Johann Joachim by name, has the following to say in reference to the subject:

"In Holland they have peat and in England pit-coals (Steinkohlen); neither of them is very good for burning, be it in rooms or for smelting. But I have found a way, not merely to burn both kinds into good coal (coke) which not any more smokes nor stinks, but with their flame to smelt equally well as with wood, so that a foot of such coal makes flames 10 feet long. That I have demonstrated with pit-coal at the Hague, and here in England at Mr. Boyle's also at Windsor on the large scale. In this connection it is noteworthy that, equally as the Swedes make their tar from firwood, I have here in England made from pit-coal a sort of tar which is equal to the Swedish in every way for some operations is even superior to it. I have made proof of it on wood and on ropes, and the proof has been found right, so that even the King has seen a specimen of it, which is a great thing in England, and the coal from which the tar has been taken out is better for use than before."

In addition to the foregoing, mention is made of this substance by Clayton in 1738, de Gensanne in 1768, and Stauf in 1771, and in 1781 a patent was granted to the Earl of Dundonald covering "A method of extracting or making tar, pitch, essential oils, volatile alkali, mineral acids, salts, and cinders from pit-coal." It will be seen from the foregoing that this substance tar

merited the attention of investigators some 200 years ago, but its manufacture was never carried out to any great extent until it appeared as a by-product in connection with the manufacture of illuminating gas, which was launched toward the end of the last century, at practically the same time, by a Frenchman named Lebon and an Englishman named William Murdoch. It appears that to Murdoch and his pupil, Clegg, must be given the credit for placing the gas industry on a firm basis. In 1815, Accum demonstrated that the quality of the tar was considerably improved by boiling, and that a valuable light oil, which could be used for a turpentine substitute, was recovered therefrom. In 1838, a marked impetus was given to the distillation of tar by the development of the suggestion on the part of Bethell that it could be used to good advantage in the preservation of timber. The industry was further advanced by the discovery of benzene in these light oils by A. W. Hofmann, in 1845, but it was the epoch-making discovery by an English chemist—William Henry Perkin—in 1856 of mauve, the first of the aniline colors, and that it could be procured in abundance from products obtainable from coal tar, that lifted this material at once from the ignominious position that it had long held to the important one which it has enjoyed ever since, not only as a source for aniline colors, but for numerous other products of scientific and commercial importance as well.

It might be gathered from the foregoing that about this time the troubles of the producers of tar were in a fair way to be overcome. Such, however, was not the case, owing to the very rapid increase in the amount of illuminating gas made and the incidental increased production of tar. Samuel Hughes, in his book on Gas Works Practice, published in 1853, states that "both tar and ammoniacal liquor are sold, the usual price for tar being 1 penny per gallon and for ammoniacal liquor 1 farthing per gallon." These prices are not much lower than obtained to-day, but it should be remembered that the amount of tar produced at this time was small and that a new industry was just being opened up. That the market was soon oversupplied is indicated, from this time on to but a comparatively recent period, by the number of patents that were taken out with the idea of opening up new uses for tar, and the never-ceasing search of the gas engineer for some outlet for a material which not only yielded him

no profit but represented a very serious inconvenience. As illustrating the condition existing in this country in the early 60's, the following letter addressed to the Editor of the *American Gas Light Journal* is of interest:

"The accumulation of tar at the various gas manufacturing establishments throughout the country is of such an amount as to put the ingenuity of those having it in charge to the test to know what to do with it. But a few years since and the demand could not be supplied; now it has become a drug on the market, no one wanting to purchase. The corporate authorities of cities and towns are taking the subject in hand, prohibiting the emptying of it into streams convenient to works—its mixture with the waters preventing cattle from drinking as well as rendering it unfit for domestic and culinary purposes. Is there no plan that can be devised to make the article of coal tar useful in its application to some purpose by which the whole or part of it might be used—or destroyed that it may not become a nuisance to the neighborhood? I trust that this article will be the means of eliciting from some of your correspondents some suggestions respecting the tar as will, in the end, result in something useful."

It does not appear from an examination of the issues of the *Journals* appearing during the next few years, that a satisfactory answer was given to the inquirer, but there is abundant evidence to show that the subject was under investigation continually, a favored outlet being born of the belief in the minds of many that the tar was an unnecessary by-product and could be converted into gas.

Those of us who have spent a good part of our lives in the gas industry—some of it directed along these unpromising but alluring lines—read with interest an excerpt from an article appearing in the *Gas Light Journal* of 1860, as follows:

"For more than thirty years coal tar has been twisted and turned in every way to give up its latent store of gaseous luminosity. It has been distilled at high heats and at low heats; with steam and without steam; with coke and without coke; with wholly spent charge of coal and the half spent charge; with iron wires, hoops and chains, with scrap iron, charcoal coals, brickbats, lime, and clay, and in fact with everything at all likely to assist in its decomposition and give rise to that all desired conclusion—the economical production of illuminating gas. At length we find after an enormous expenditure of time, talent, and money, that practically the thing can not be done to pay—consequently it can not be done at all."

Since 1860 the development of the tar distilling industry has been enormous, new uses being found for the products obtained therefrom, chiefly along the lines of wood preservation and in the

preparation of pitch for roofing purposes, and for the last 20 or 30 years it has been comparatively easy for gas works to dispose of their products, if of fair quality, at a price which while low at least enables them to rid themselves of it at a profit.

I am indebted to a paper by S. R. Church, Manager Research Department, Barrett Manufacturing Company, and read before a recent meeting of the Southern Gas Association, for the following history bearing upon the development of the tar distilling business in this country:

"A very considerable business in the refining of the by-products of the gas works had sprung up and flourished before the introduction of by-product ovens. So far as the writer has been able to learn, this industry, based on gas works tar and ammonia liquor, was developed independent of the gas works engineers and managers, by a number of entirely separate concerns and individuals. Among the pioneers in the industry were Cyrus M. Warren and his brothers.

"Cyrus M. Warren was educated at Harvard University, and on the advice of Professor Agassiz, went to Germany, where he studied chemistry under Liebig, and became interested in coal tar. Mr. Warren was possibly the pioneer in the industry in this country.

"In the early sixties Samuel Page started distilling coal tar in Boston, and shortly afterwards his brothers, under the style of Page Brothers, started business in New York City, where they were succeeded by Page, Kidder and Fletcher. Mr. I. D. Fletcher, now President of the Barrett Manufacturing Company, became associated with the Pages early in the sixties. At about the same time Mr. Fletcher's brother established what was probably the first tar refinery in the South, at New Orleans.

"Major S. E. Barrett and his associates, who started in Chicago, were among the pioneers of the same industry, as were Levi L. Wilcutt and Joseph C. Storey of Boston, Chapman and Soden of Boston, and A. T. Perry, who was associated with Cyrus M. Warren, and later went to Cleveland, where he established a tar refinery.

"Others who were engaged in the industry in the early times were: W. H. Childs of Brooklyn, Michael Ehret of Philadelphia, and P. S. Marquis of St. Louis."

Such briefly is the history of one of these important by-products, and no less interesting and of equal value is another—ammoniacal liquor from which is produced most of the ammonia of commerce.

The salts of ammonia have been known from the earliest antiquity. Pliny, Hippocrates, and Discorides made frequent mention of "ammoniakon," and Herodotus refers to "hals ammoniakos," as do other authors up to the sixth century. The name ammonia appears to have been given to it by Berthollet, to

whom credit must also be naturally given for determining its composition.

While ammonia occurs in combination in many natural occurring substances, it is from gas works liquor that the bulk of the supply is now obtained. Numerous observers demonstrated that it could be obtained from the destructive distillation of animal refuse, peat, vinasse, etc., but time does not permit a review of the investigation and research work which has been carried out on this product by chemists and others from the earliest days of the gas business. It appears, however, that there was never a time when it was regarded as an undesirable product such as was tar, because its value as a fertilizer was early recognized, and in this direction it could be employed in unlimited quantities.

Statistical.

As illustrating the enormous increase in product of ammonia and tar in this country during the past ten years, the following table taken from the Mineral Resources of the United States, 1912, is of interest.

PRODUCTION OF GAS, COKE, TAR AND AMMONIA, AND VALUE THEREOF, AT COAL GAS WORKS AND BY-PRODUCT COKE OVENS IN THE UNITED STATES, 1903–1905, 1907–1908, AND 1912.

	1903		1904	
	Quantity	Value	Quantity	Value
Gas sold.....1000 cu. ft.	31,049,462	30,315,776	34,814,991	32,090,998
Coke.....short tons	3,941,282	13,634,095	4,716,049	14,693,126
Tar.....gallons	62,964,393	2,199,969	69,498,085	2,114,421
Ammonia (reduced to NH_3).....pounds	17,643,597	1,291,732	10,750,032	1,487,196
Ammonium sulphate.....pounds	12,400,032	389,028	28,225,210	771,995

	1905		1907	
	Quantity	Value	Quantity	Value
Gas sold.....1000 cu. ft.	40,454,215	32,937,456	54,819,685	36,462,304
Coke.....short tons	5,751,378	18,844,866	8,093,144	30,332,644
Tar.....gallons	80,022,043	2,176,944	103,577,760	2,651,527
Ammonia (reduced to NH_3).....pounds	22,455,857	1,728,254	37,560,858	2,601,057
Ammonium sulphate.....pounds	38,663,682	997,452	48,882,237	1,525,472

	1908		1912	
	Quantity	Value	Quantity	Value
Gas sold.....1000 cu. ft.	53,561,811	37,227,901	89,603,372	36,681,884
Coke.....short tons	6,253,125	21,507,045	12,490,757	48,380,009
Tar.....gallons	101,261,829	2,537,118	134,796,438	3,802,047
Ammonia (reduced to NH_3).....pounds	30,615,835	2,065,169	51,527,074	4,776,386
Ammonia sulphate.....pounds	44,093,437	1,322,807	99,070,777	3,740,075
Ammoniacal liquor.....gallons	.....	.....	35,242,549	1,002,807

It will be seen that both the tar and ammonia production more than doubled during the above mentioned period.

As might be gathered from the foregoing, the proper recovery of these by-products now receives almost, if not quite as much, attention as the proper manufacture of the primary product, and the modern gas engineer must design his plant with the dual object in view of producing a gas satisfactory from an illuminating and calorific standpoint and commercially pure, and at the same time give due consideration to a proper conservation of the by-products in a form best suited for their most profitable utilization.

Recovery.

Having briefly reviewed the history of the two principal products under consideration, I will now endeavor to explain the method by which they are recovered in a modern gas plant and made suitable for the market, and since quite a considerable portion of these by-products are recovered at almost every step in the process, clearness requires that the ordinary methods of gas manufacture be briefly considered along with a more detailed account of the special apparatus employed. It will suffice also to consider only the manufacture of coal gas which yields both tar and ammoniacal liquor, whereas tar alone is produced as a by-product in the manufacture of water gas.

It should be stated here that coal gas is usually produced from a high volatile coal containing from 35 to 38 per cent. of volatile combustible matter. A typical analysis of such a gas coal, both proximate and ultimate, is as follows:

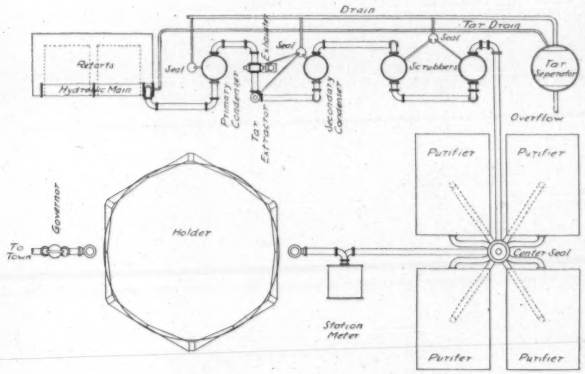
Proximate		*Ultimate*	
Moisture	2.2 per cent.	Carbon	78.4 per cent.
Volatile combustible	38.1 per cent.	Hydrogen	4.8 per cent.
Fixed carbon	53.2 per cent.	Nitrogen	1.5 per cent.
Ash	6.5 per cent.	Sulphur	1.3 per cent.
		Oxygen	7.4 per cent.
		Ash	6.6 per cent.

The manufacture of illuminating gas in a modern gas plant may be divided into three operations; the first involving the generation of the crude gas from the raw material; the second, its purification; and the third, its distribution.

In Figure 2 is shown a plan layout of a coal gas plant provided with apparatus necessary for the generation and proper purification of the gas and the recovery of the by-products in

their crude form. Basically, there has been very little change in the general methods of coal gas manufacture, by the horizontal retort method, since the beginning of the industry. The various pieces of apparatus have, however, been improved and in some few instances supplanted by others of a radically different type. The practice, however, of cooling the gas by means of air- or water-cooled condensers for the purpose of freeing it from the greater portion of its suspended tar before it enters the ammonia washers has generally been regarded as essential and has been, up to very recent years, universally followed.

FIG. 2.



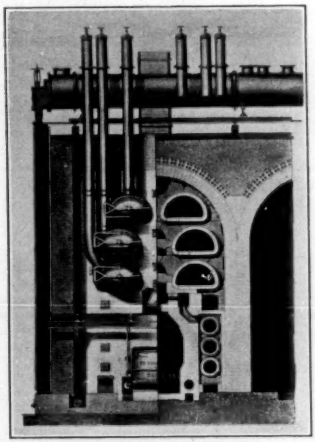
Arrangement of coal gas plant.

In Figure 2, the battery of retorts represents the generating apparatus. Following this is the condensing and scrubbing apparatus and the four-box purifying system. The functions of these various pieces of apparatus and the part they play in the production and recovery of the two principal by-products will be more clearly understood from a consideration of their construction in more or less detail.

Figure 3 shows a bench of six retorts, although a larger number is quite frequently employed. The illustration shows three of the retorts with mouthpieces and stand pipes removed. It will be seen that they are ⊐ shaped in cross section. They

are however sometimes elliptical or circular and even rectangular. The ordinary stop-end retort is about 9 feet long, 26 inches wide, and 15 inches high, and is capable of handling a charge of from 350 to 400 pounds of coal every 4 hours, the retorts being maintained at a light cherry-red heat by means of the furnaces placed within the retort setting. The furnaces are usually fired with a portion of the coke remaining in the retort after the gas is expelled. The gas derived from the volatile portion of the coal,

FIG. 3.



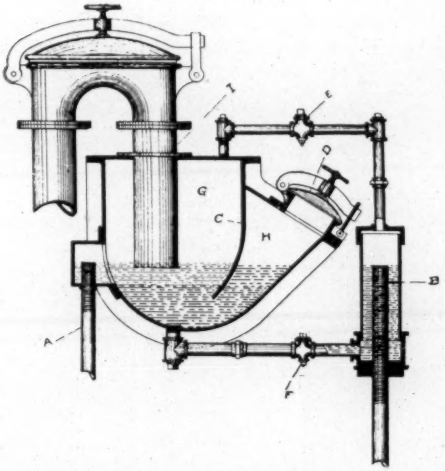
Coal gas retorts.

rises through the stand pipes and passes through dip pipes into the hydraulic main, loaded with tar, and water vapor carrying ammonia and other impurities in solution. The ends of the dip pipes are sealed in ammonia liquor maintained at a constant level in the hydraulic main (see Figure 4). This liquor, which floats on the surface of the heavier tar lying in the bottom of the main, is deposited in an amount sufficient, not only to maintain the seal at all times, but an excess is produced which is carried away to the receiving tank, by way of an automatic overflow, the

tar passing out of the main to the tar well through an overflow which may or may not be automatic.

The passage of the gas through the seal in the hydraulic main reduces its temperature to 160° F. or thereabouts. This reduction in temperature is the chief cause of the precipitation of a large quantity of water vapor, containing ammonia in solution, and tar. Generally about 60 to 70 per cent. of the total tar produced is deposited at this point together with from 10 to 15

FIG. 4.



Cross section of hydraulic main.

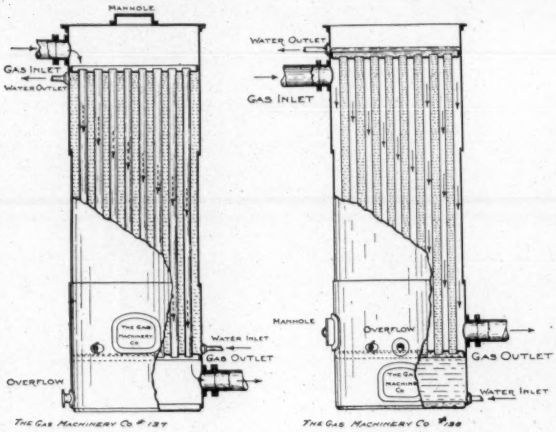
per cent. of the total ammonia. As might be expected, the heavier tars containing a high percentage of free carbon are deposited first together with ammoniacal liquor in which the fixed salts of ammonia predominate, the more volatile salts, such as carbonate and sulphide, being driven forward with the gas.

On the following table is shown an analysis made in the author's laboratory of hydraulic main ammoniacal liquor compared with an analysis of an average sample of the total liquor produced.

Figures represent grains per United States gallon	Well	Hydraulic main
Total NH_3 found by direct distillation	1446	362
Total NH_3 as calculated from the sum of component salts	1440.3	316.0
NH_3 as monocarbonate	1283.0	36.7
NH_3 as monosulphide	81.7	6.5
NH_3 as monothiosulphate	8.7	46.6
NH_3 as monosulphate	4.5	6.4
NH_3 as monochloride	32.1	192.4
NH_3 as monosulphocyanide	26.8	26.2
NH_3 as monoferrocyanide	3.5	1.2
NH_3 as monocyanide	....	....

As the gas leaves the hydraulic main, it still contains from 300 to 350 grains of ammonia per cubic foot together with tarry vapors and other impurities. The next step in its purification is a further cooling to about 105° F. This is accomplished by

FIG. 5.

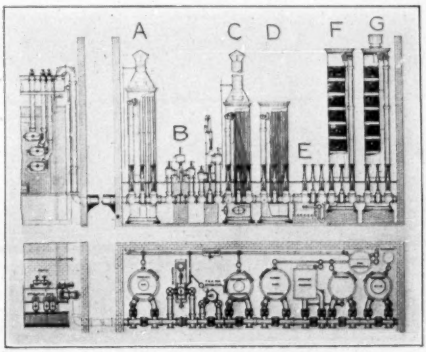


Multitubular condenser. Water tube condenser.

means of a primary condenser, usually a cylindrical vessel set vertically and provided with tubes through which the gas or cooling water flows (see Figure 5). Water circulates around the tubes in the multitubular type and through the tubes in the water tube type. In Figure 6 the primary condenser is shown at "A."

The gas having been cooled, passes into the tar extractor which is shown at "B" (Figure 6). In detail this apparatus is shown in Figure 7. Its operation is dependent upon the passage of the gas at high velocity through perforated plates set in such a relation to one another that the gas after passing through the perforation strikes against the surface directly opposite. The passage of the gas through the small perforations agglomerates the tarry mist, its deposition being further assisted by the gas striking upon baffling plates on which the tar is deposited. Provided the temperature is favorable, it is possible to more or less completely remove the tar from coal gas by means of such an

FIG. 6.



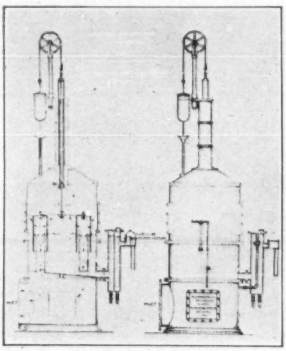
Condensing and scrubbing plant.

extractor and it then remains only to remove the ammonia. This is effected by further cooling of the gas in secondary condensers (see "C" and "D," Figure 6) to about 65° F. and passing it into the tower scrubber "F," in which it is scrubbed with weak ammoniacal liquor, usually that collected from the condensers, hydraulic main, and from the second tower scrubber, which is supplied with fresh water. These scrubbers are filled with grids or coke over which the scrubbing liquor or water flows, presenting a large scrubbing surface to the passing gas. In this manner a liquor is produced containing from 1 to 1½ per cent. of ammonia, depending upon the efficiency of the apparatus and the amount of water supplied.

From the tower scrubbers the gas, now freed from its tar and ammonia, passes to purifiers such as shown on Figure 2, to be freed from hydrogen sulphide. These purifiers are usually large rectangular boxes with removable lids containing shavings coated with oxide of iron. The sulphuretted hydrogen reacts with the iron oxide forming iron sulphide and the gas finally passes into the storage holder commercially pure and ready for distribution, the tar and ammonia liquor being collected in storage wells or tanks provided for the purpose.

A good grade of gas coal will produce, in horizontal retorts, from 12 to 14 gallons of tar per net ton of coal carbonized and

FIG. 7.



P. & A. tar extractor.

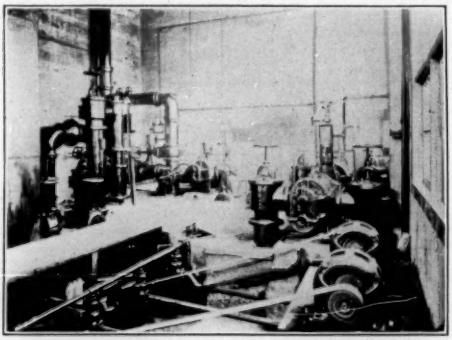
from 4½ to 5½ pounds of ammonia. This amount of ammonia contained in a 1.5 per cent. liquor requires the approximate production of from 36 to 44 gallons of weak liquor per net ton of coal carbonized. A portion of this liquor is derived from the solution of ammonia evolved, in the moisture originally present in the coal and in the water of formation, the balance of the water is supplied extraneously for the purpose of completely removing the ammonia from the gas.

The following example shows the amount of water from various sources per net ton of coal, based on a 1.5 per cent. liquor and a 5-pound ammonia yield:

Moisture from coal	2.0	per cent. = 40.0 pounds =	4.8 gallons
Water of formation	5.5	per cent. = 110.0 pounds =	13.2 gallons
Fresh water added	9.6	per cent. = 192.0 pounds =	23.1 gallons
Total water from all sources	17.1	per cent. = 342.0 pounds =	41.1 gallons
Less water carried away in gas at temperature of station meter	.46	per cent. = 9.2 pounds =	1.2 gallons
Total liquor	16.64	per cent. = 332.8 pounds =	39.9 gallons

The foregoing description covers briefly the recovery of tar and ammoniacal liquor by means of standard apparatus, the simplicity of which has stood the test of time. As might be expected, however, special forms of scrubbers and condensers have been designed with the idea of securing higher efficiencies and reducing the number of separate pieces of apparatus required.

FIG. 8.



Washer cooler showing motor-driven circulating pumps.

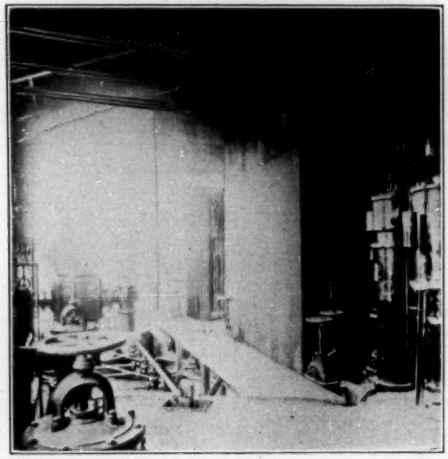
Perhaps the most radical departure from the older methods of condensing and scrubbing gas is exemplified in the so-called washer cooler. In this apparatus the laws governing the cooling of gas and the transfer of heat were fully taken into account and a successful attempt was made to obtain a much higher efficiency from the cooling water than was possible in the old style condensers.

This was accomplished by spraying the cooling water directly into the gas without the interposition of a metal diaphragm such as is represented by the condenser tubes. The water after going through the scrubber is brought back to its original temperature

by passing it through a cooler or surface condenser over which small streams of water trickle.

In this method of procedure heat is transferred direct from the gas to the water without having to pass through the walls of condensing tubes, and from water to water. While the transferal in the second step is through an interposing diaphragm, this is not serious when transferring from water to water, although the efficiency is very much lower when transferring heat in this manner from gas to water.

FIG. 9.



Washer cooler showing overhead liquor delivery pipes.

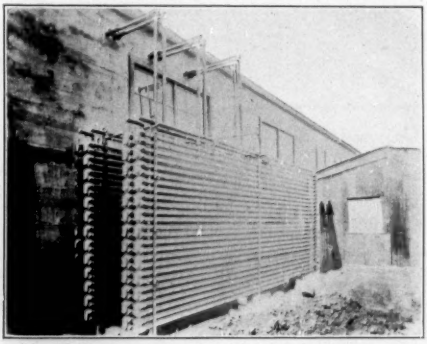
The apparatus is built either circular or rectangular in shape. In the latter case it is divided into 6 or 8 compartments. Each compartment is connected with a rotary pump which carries the water from the bottom of the compartment through cooling coils placed usually outside of the apparatus and sprays it into the top.

In Figure 8 is seen the motor driving the circulating pumps; in Figure 9 the scrubber in position with overhead pipes discharging into the top of the scrubber, and in Figure 10 are shown the cooling coils placed outside the building.

The bottoms of the compartments are connected in such a manner that the liquor or water can flow successively through all of the compartments and out at the gas inlet, and by introducing a small stream of fresh water at the outlet compartment, the apparatus can be made to act also as a very efficient ammonia scrubber.

In Figure 11 is shown a multiple ammonia washer. This apparatus is intended to be operated before the ammonia scrubber. Its purpose is the preliminary treatment of the gas with the liquor from the tower or rotary scrubber for removal of ammonia and mechanically suspended matter. It is claimed that the large

FIG. 10.



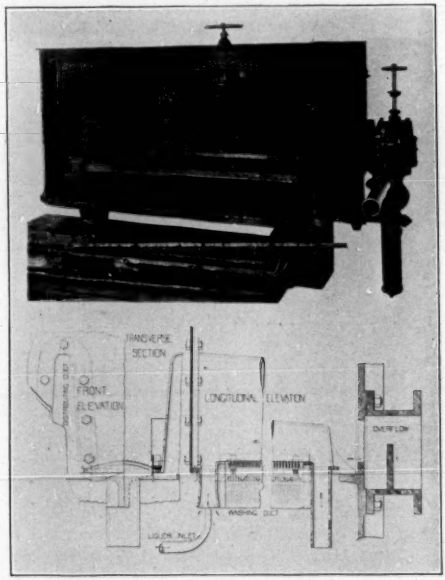
Washer cooler showing cooling coils.

percentage of ammonia here absorbed materially increases the strength of the liquor, while the coincident removal of carbon dioxide and sulphuretted hydrogen increases proportionally the efficiency and capacity of the scrubbers and purifiers. The washer also carries part of the load when it is necessary to temporarily by-pass the tar extractor for repairs in the works.

The washer here described consists of a rectangular box containing a number of cast-iron distributing ducts closed at the back. The open end is bolted to a steel apron forming the inlet chamber of the washer into which the gas enters and passes into the ducts through their open ends and then under the serrated edges of the washing ducts located between the distributing ducts.

The gas in reaching the outlet compartment is subdivided by the serrated submerged edges of the distributing ducts, under which it must first pass, when a second division takes place in its passage through the perforated sides of the washing ducts, and finally through the perforations of the crown sheet, which is covered by the washing liquor in a high state of ebullition.

FIG. 11.



Multiple ammonia washer.

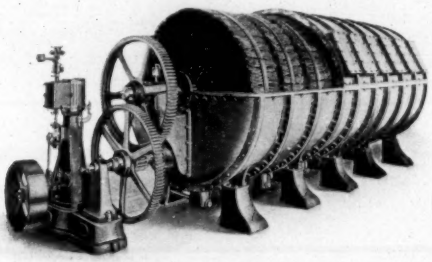
While primarily this apparatus is not intended in any sense to replace the tar extractor, it undoubtedly removes a considerable quantity of tar and at times proves very useful in preventing tar from being carried forward into and fouling the ammonia washer.

Figure 12 shows a mechanical or rotary ammonia scrubber, designed to secure more intimate contact between the ammonia

compounds in the gas and the absorbent than is possible in the tower type. Its action is based on the principle that the ideal scrubber is one in which the greatest wetted surface is obtained in the smallest gross volume. Some mechanical scrubbers are provided with wooden grids, others with iron plates, and still others with fibre brushes. The scrubber shown is of this last construction.

The brushes are fastened to a shaft which is made to revolve, and as the scrubber is about one-third filled with water, the brushes continually rising from the water present freshly wetted fibres to the passing gas. The wetted surface presented is very large, and it is possible with this scrubber to obtain a liquor con-

FIG. 12.



Rotary scrubber.

taining over 5 per cent. of ammonia, at the same time reducing the ammonia content of the gas to less than three grains per 100 cubic feet.

It is claimed that scrubbers so equipped have successfully handled over 2000 cubic feet of gas per day per cubic foot of gross volume, this being rendered possible by the brush construction, which gives 42 square feet of wetted surface per cubic foot of gas passed per minute and 91 square feet of wetted surface per cubic foot of actual gas passageway; in other words, over 30 square feet of wetted surface per 1000 cubic feet of gas passed per day. The enormously increased capacity is appreciated when it is considered that ordinary tower scrubbers require 15 cubic feet gross volume per 1000 cubic feet of gas per day.

Through the courtesy of the builders of this apparatus, I

am able to give a working test, which shows a very high efficiency in respect to ammonia removed, and also that a very considerable amount of carbon dioxide and sulphuretted hydrogen were removed at the same time:

Ammonia (NH_3) in gas at inlet	45.10 grains per 100 cu. ft.
Ammonia (NH_3) in gas at outlet	.13 grains per 100 cu. ft.
Ammonia (NH_3) in gas removed	99.7 per cent.
Carbonic acid (CO_2) in gas at inlet	4.6 per cent. by volume
Carbonic acid (CO_2) in gas at outlet	4.0 per cent. by volume
Carbonic acid (CO_2) removed	13.0 per cent.
Sulphuretted hydrogen (H_2S) in gas at inlet	2.2 per cent. by volume
Sulphuretted hydrogen (H_2S) in gas at outlet	.8 per cent. by volume
Sulphuretted hydrogen (H_2S) removed	63.6 per cent.
Rated capacity of rotary scrubber	3,500,000 cu. ft. per diem
Gas treated by rotary scrubber	4,090,000 cu. ft. per diem
Overload 17 per cent. 56/100 gallon water used per 1000 cu. ft.	

Figure 13 shows a plant layout with tower scrubbers replaced by a multiple washer and rotary scrubber.

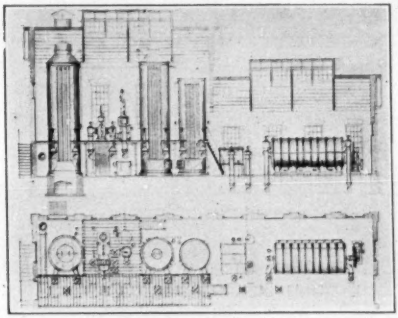
A scrubber that is considered by many as a distinct advance over the tower or rotary type, is the so-called Intensive Scrubber shown on Figure 14. This scrubber is divided into compartments resembling somewhat a number of tower scrubbers in series, the gas passing up through the grids while the washing liquor flows down over and through the same grids and in intimate contact with the gas.

Figure 15 shows the scrubber with some of the plates removed showing the grids in place. A steam engine or motor drives the countershaft operating the pumps which carry the washing liquor to the tops of the various compartments (see Figure 16).

At the base of the scrubber are decanting chambers, one for each of the compartments. These are kept full of liquor to the top of the weirs, by fresh water supplied into the last chamber. The liquor flows in succession into and through all of the chambers and passes out of the apparatus at the liquor overflow on the first or inlet gas compartment. The liquor in the various compartments is kept separated by the weirs above referred to. The tops of these weirs are at a gradually descending height from outlet to inlet; the liquor in the adjoining compartments is thus prevented from mixing. The liquor in the decanting chamber of each compartment is handled by its own pump, which carries it continuously to the top of the chamber, where it is distributed over the grids.

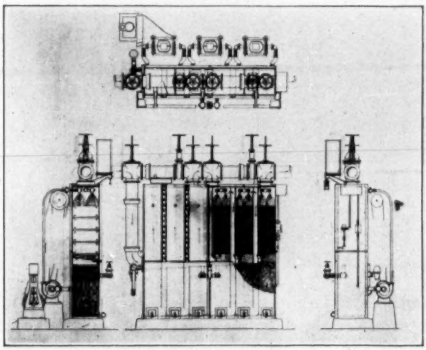
The gas enters the first compartment, and rising through the scrubbing plates therein meets the descending liquor, which is sprayed into the top of the compartment. The gas then passes

FIG. 13.



Coal gas condensing and scrubbing system with rotary scrubbers.

FIG. 14.



Intensive scrubber

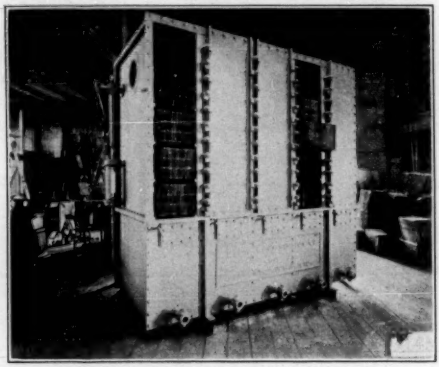
down through the conduit formed by the division walls, enters the bottom of the second compartment, rising through the grids, and descending to the third compartment, and so on to the outlet;

in each successive step losing a portion of its ammonia as it meets the weaker liquor flowing in the reversed direction.

The construction of the apparatus and the operation of the sprays insures a thorough wetting of the very large surface exposed, permitting operation at high efficiency.

The advantages claimed for the Intensive Scrubber over tower scrubbers are—much less space occupied and the possibility of producing a high strength liquor with a very small quantity of water. As compared with rotary scrubbers, the makers claim a number of advantages in addition to the fact that the scrubber occupies less space. All of the scrubbing surface is continually

FIG. 15.



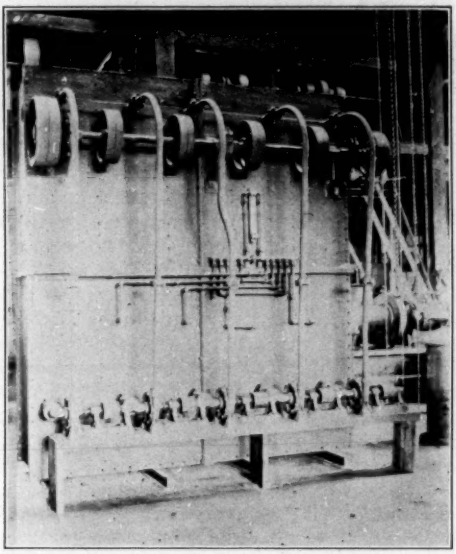
Intensive scrubber (with grids exposed).

in use, which is not true of rotary scrubbers, wherein a portion of the grids or brushes are at all times submerged.

The constant efficiency of all of the scrubbing surface is also one of the claimed advantages. It is pointed out that in the Intensive Scrubber, the liquor on any given area of scrubbing surface is always at the same degree of saturation of ammonia, and hence, has a constant absorptive power. But in all rotaries, the scrubbing surface is rotating while the gas is passing through the scrubbing drum radially. Hence there is a continual decrease in absorptive power of the liquor adhering to the emerged grids in each revolution, as the rotation proceeds, until towards the end

of it, the adhering liquor has come into equilibrium or equal vapor tension with the gas and some gas will, therefore, pass through without leaving any ammonia in that section. The portion of the free revolution during which it will absorb ammonia, is a variable, determined by the speed of rotation and the quantity of gas passing. In the Intensive Scrubber, on the

FIG. 16.



Intensive scrubber. (Showing motor-driven circulating pumps.)

contrary, there is a continual application of the contracurrent principle, whereby foul gas is always meeting cleaner liquor.

Another feature upon which considerable emphasis is laid is, that owing to the large amount of scrubbing liquor continually passing through the grids, they are very little unlikely to become fouled with naphthalene or tar, the heavier tar being carried to the bottom of the compartment, below the level from which clean liquor is drawn.

This apparatus is often worked in combination with the washer cooler, and together they constitute a condensing and scrubbing system entirely different from the old style apparatus, and the best evidence of the practicability and efficiency of the system is the steadily increasing number of installations throughout the country.

Irrespective of the type of apparatus employed, the tar and ammoniacal liquor are finally collected into separate wells or tanks. The tar contains a small amount of ammoniacal liquor, usually not over 6 or 7 per cent. The ammoniacal liquor contains 1.5 per cent. or over total ammonia, in which state it is ready for further concentration. The tar is usually sold to tar distillers without further refinement, but in order to reduce transportation charges, the ammoniacal liquor is concentrated until it contains from 15 to 20 per cent. of ammonia.

Before entering upon a description of the apparatus employed for concentration, mention should be made of a direct system of ammonia recovery which, although it has not been extensively employed in gas plants, has proven entirely practicable and highly efficient in coke oven practice. There appears to be no good reason why it should not be well adapted to the conditions found even in a modern sized gas works, and experience abroad, where it has been tried, has justified the above conclusions.

The general layout of the plant is shown on Figure 17. The gas from the ovens passes first to a series of condensers of the multitubular type, which reduces the temperature to a point where the tar can be completely removed by a P. & A. condenser. The gas then passes to a reheater, where it is brought to about 160° F. From thence it goes to a saturator containing sulphuric acid, where the ammonia is absorbed, forming ammonium sulphate. The condensates from the primary condensers and the tar extractor are conducted to an ammonia still, where they are treated with lime for the purposes of recovering the fixed ammonia, the vapors from the still being passed into the gas main and a complete conversion of the ammonia in the gas into sulphate is thus accomplished. This system entirely eliminates the necessity for ammonia washers and concentrators, and possesses other decided advantages.

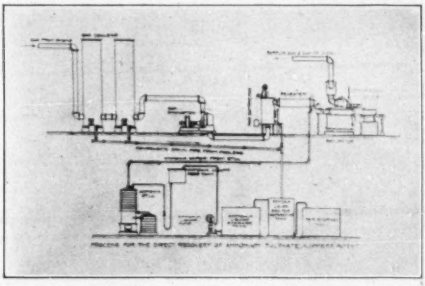
In a somewhat similar system, the tar is removed at high temperature by scrubbing the gas with a tar spray which removes all of the tar but very little of the ammonia. The gas

then carrying practically the full content of its ammonia passes into a saturator and is converted into sulphate as in the first process.

As before stated, it is the general practice in this country to merely concentrate the weak liquor obtained in the ordinary process of condensing and scrubbing the gas in order to save the freight on excess water.

Two prominent types of stills are employed: one known as the *continuous type* and the other as the *continuous feed-intermittent effluent type*. In the first form the liquor is fed into the still continuously and the waste passes from the still continuously. In the second form, the liquor is fed into the still continuously,

FIG. 17.



Process for the direct recovery of ammonium sulphate.

but the waste is drawn off intermittently. On Figure 18 is shown a well-known example of a continuous still.

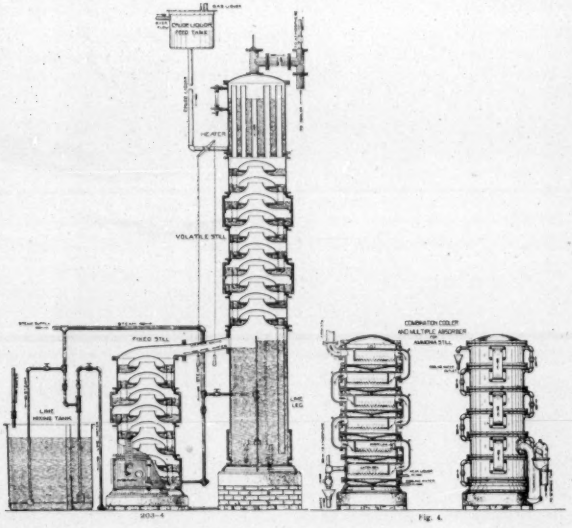
The apparatus illustrated shows a still of medium size, but the internal arrangement is the same in all, from twenty-four inches to eighty-four inches in diameter. The eighteen-inch machine operates on the same principle, and differs only in that there are somewhat fewer parts.

For a proper understanding of the action of the still, it may be well to trace the flow of liquor from the well through the apparatus. A pump lifts the liquor to an overhead feed tank, from which it passes to the heater, where it is preheated by the vapors rising through cast-iron pipes fitted into the diaphragm, which separates this unit from the first section of the still.

The liquor overflows into the central one of these tubes,

which is somewhat shorter than the others, and passes into the top chamber of the volatile still, which consists, as shown by the illustration, of a series of chambers provided with baffles and overflows. The liquor, in descending from chamber to chamber, is brought into intimate contact with the hot, rising vapors and reaches the lower section freed of its volatile ammonia. The liquor then passes through the dip pipe down into the lime leg,

FIG. 18.



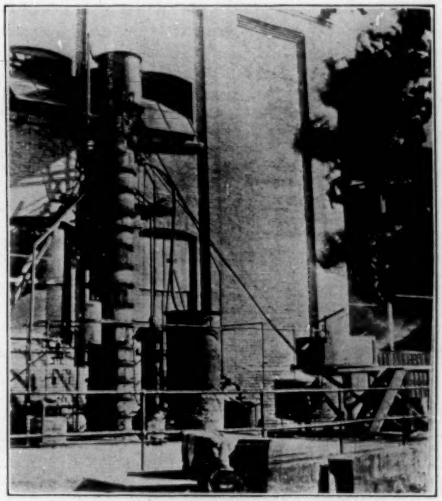
Continuous type of ammonia concentrator.

where it is brought in contact with the lime just as it enters at the bottom of the still. The arrangement shows the manner in which the combined liquor and the milk of lime are made to traverse the entire length of the lime leg twice before overflowing to the fixed still, thereby insuring extended and intimate contact between the lime and the fixed salts. Steam inlets are provided in the base of the lime leg on each side of the vertical

diaphragm, both for the purpose of increasing the temperature at this point as well as for stirring up the lime mixture.

The liquor and lime water finally overflow into the top section of the fixed still and down through a series of chambers identical in construction with those of the volatile still. When the bottom section is reached, the waste liquor passes to the sewer and contains only a very small amount of ammonia, usually not over 0.005 or 0.01 per cent.

FIG. 19.



Continuous ammonia concentrator.

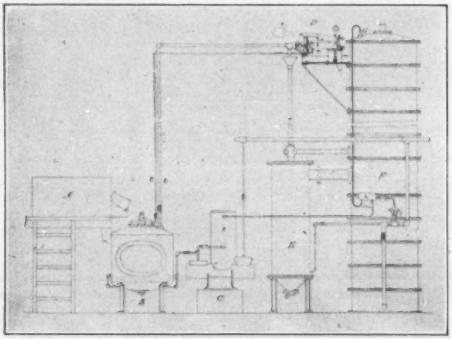
Figure 19 shows another prominent type of continuous still. Its general plan of operation is similar to the type above described. In detail, this apparatus is shown on Figure 20.

The still illustrated has six sections in the volatile still, with partitions between them and partitions cast in, so there are eleven compartments, and six sections, each of one compartment, in the fixed still. The liquor enters at top in a steady stream, descends through the three compartments of the washer and is deflected

into an outside pipe leading into the bottom of the heater, in which it is heated to about 190° F., and overflows near the top of the heater into an outside pipe leading to the tenth compartment of the volatile still. The liquor in the heater surrounds a number of lead pipes in which circulate the hot vapors coming from the still, the condensate in the pipes returns to the still and the cooled vapors pass through the side of the heater into a tee, containing a thermometer and a thermostat, for regulating the steam supply, and then into the lead pipe coil of the condenser.

The bottom end of the lead pipe protrudes through the side of the condenser and is bent downwards in the shape of a goose-

FIG. 20.



Continuous ammonia concentrator showing construction detail.

neck into the centre of the absorber, and extends half-way into the concentrated liquor. The concentrated liquor overflows into the pipe leading to the storage tank through a seal made of cast iron flanged fittings, in which there is an overflow casting containing a bell-glass.

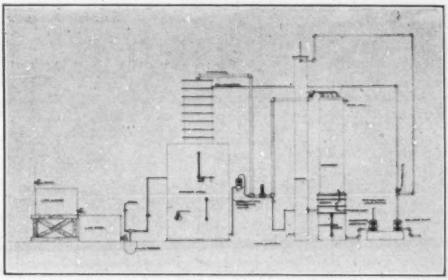
The automatic valve for feeding the milk of lime is placed on a support between the heater and condenser, above the funnel and on top of the pipe coming from the lime leg, and discharges about half a gallon of milk of lime at time intervals, depending upon the amount of milk of lime required. The mixture of hot liquor and lime overflows from the lime leg into the top of the fixed still, in

which it is subjected to heavy boiling through deep seals and gradually freed from the ammonia, so there need not be more than 0.005 per cent. ammonia in the waste escaping from the bottom compartment.

Figures 21 and 22 are two views of a still of the continuous feed-intermittent effluent type. In this still the liquor is fed continuously but the effluent is drawn off usually at two-hour intervals.

By referring to Figure 22 the operation of the still will be understood. A dephlegmating column similar to those previously described is placed on the top of a cylindrical tank set vertically. This tank is divided into two compartments having hopper bot-

FIG. 21.



Continuous feed-intermittent effluent concentrator.

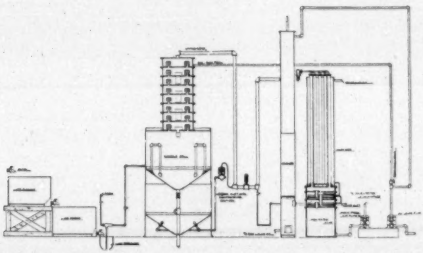
toms, the compartments being connected through an opening in the apex of the cone. This opening is controlled by a cock which can be operated from the outside of the still, and permits of the passage, at will, of the liquor from the top compartment to the bottom compartment. Steam inlets are provided, as shown, in the bottom compartment. The top of the column is connected through a goose-neck with tubular condenser and receiver and means are provided for introducing milk of lime. The operation of the still is as follows:

The liquor is fed into the top of the column, flows down through overflows sealed in liquor until it finally discharges into the top section of the still. In its descent it meets the ascending steam charged with ammonia vapor. The capacity of the still is

such that the top compartment will be filled about two-thirds in two hours. The cock connecting the two compartments is then opened and its content dropped into the bottom compartment, milk of lime having been added to the liquor before it is dropped to the bottom compartment. Just before again dropping the contents of the top compartment, the lower compartment is discharged into the sewer, practically all of the ammonia, both fixed and volatile, having been driven from the liquor.

The still is exceedingly simple to operate, and, in the opinion of many, possesses decided advantages over the continuous effluent type. Chief among these is the perfect control over the character of the waste, in respect to ammonia content, obtained by the intermittent discharge.

FIG. 22.



Continuous feed-intermittent effluent concentrator, showing vertical section.

In conclusion, brief mention should be made of another gas works by-product, cyanogen, which, although extensively recovered abroad, has received, up to the past few years, but little attention in this country. Recently, however, one large gas company has installed apparatus for cyanide recovery, and good results are reported.

Cyanogen occurs in coal gas as free cyanogen $(CN)_2$ and hydrocyanic acid (HCN), both of which are gases. It is formed by the combination of a small percentage of nitrogen contained in the coal, with the necessary amount of carbon. The amount occurring in the gas is dependent upon the temperature of distillation, high heats being conducive to a high cyanogen yield. A temperature of about 1735° F. is said to be most favorable.

The yield of hydrocyanic acid will then be between two

and three ounces per thousand feet of gas. It is rare in this country that as much as three ounces are produced, owing to the comparatively low heats carried. Several tests made in an American gas works showed something over two ounces; being higher at one station than at another in the same works, due, presumably, to slightly different heats carried.

At works where no attempt is made to remove the cyanogen from the gas, about 10 or 15 per cent. is taken out in the ammonia scrubbers, and the rest more or less completely removed in the purifiers, occurring there as Prussian blue. Up to a few years ago, the spent purifying material was the chief source of cyanides, but it was soon recognized that only a portion of the whole could be recovered in this way, and attention was given to its recovery from the gas itself.

Numerous processes have been devised for wet scrubbing, the earliest being the Knublauch System, which system consisted in bringing the gas, by means of a mechanical scrubber, into intimate contact with a solution containing an alkali and the salt of a heavy metal, preferably iron. In this way, soluble ferrocyanides are formed and recovered from the wash liquor by evaporation and crystallization.

There were several defects in the Knublauch system and at present it has given way to other systems which are more efficient and more easily controlled. All of these, however, except perhaps the process exploited by the British Cyanide Company are based upon the Knublauch principle. A brief outline of the most important systems in use to-day is as follows:

Feld Process.

In the Feld system, the cyanide washed is placed immediately after the ammonia scrubber, operating on gas freed from ammonia. The washer employed is usually of the standard rotary or bubbling type. Solutions of lime and ferrous sulphate are used as the scrubbing material, being introduced separately and continuously into the washer. The product obtained is a solution of calcium ferrocyanide, from which the pure salt can be crystallized.

Stavorinus Process.

In the Stavorinus process the washer is placed immediately after the tar extractor and operates therefore on gas *containing* ammonia. The scrubbing material employed is a solution of po-

tassium carbonate, and iron carbonate made from ferrous sulphate in suspension. The product obtained is a soluble alkaline ferrocyanide. Although the system is arranged for a continuous flow, the process is really intermittent.

Two or three times a day a quantity of saturated liquor is drawn from the last bay of the scrubber and fresh liquor poured in. Since a large amount of ammonia is dissolved with the soluble cyanide, it must be recovered by boiling off in some form of concentrator. The residual sludge is then pumped into a filter, where it is converted into a clear solution and a cake, the solution consisting of potassium ferrocyanide, potassium sulphide, and potash. This liquor is evaporated until it throws down the salt.

British Cyanide Process.

In this process the gas is treated, immediately after the tar extractor, as in the Stavorinus process. A mechanical scrubber is employed having nine bays. Over eight of these bays is fixed a conical cup for holding the sulphur. Ammoniacal liquor is pumped into the washer at the outlet end, and granular sulphur is introduced intermittently into the eight bays. Ammonium sulphocyanide is formed and is disposed of as such.

Bueb Process.

In the Bueb process the cyanide washer is placed after the tar extractor. This process also operates on gas containing ammonia. A ferrous sulphate solution is employed as the scrubbing material. The product produced is a mixture of insoluble cyanides, which is sold in its crude state.

Another by-product of less importance, but having some commercial value, is the sulphur which separates out in the revivification of spent oxide. This accompanies, however, in coal gas practice, a considerable quantity of cyanogen and the value of the oxide when sold is usually based on its cyanogen content rather than on the sulphur, though the latter may be used for the manufacture of sulphuric acid.

While in the foregoing paper chief consideration has been given to tar and ammoniacal liquor, the fact should not be lost sight of that the coke produced is in reality the most valuable of all of the by-products. In ordinary gas works practice, after deducting that necessary for heating the furnaces, there will be left for sale an amount equal to about fifty per cent. of the coal

carbonized. Analysis of a typical gas house coke is about as follows:

Moisture	.16 per cent.
Volatile combustible	1.46 per cent.
Fixed carbon	88.80 per cent.
Ash	9.58 per cent.
B. T. U's per pound	12,240

It is extensively used for domestic and furnace purposes, and usually finds a ready sale at from $3.00 to $5.00 per ton, representing, as it does, a clean smokeless fuel at moderate cost and high heating value.

I have endeavored in the foregoing paper to describe the general methods of procedure in a modern gas works, in the recovery and preparation for market of the most important by-products, and also to give a brief description of apparatus, representing the most approved practice at the present time.

A great deal has been written on the general subject of gas manufacture and much also bearing upon the industry of tar and ammonia distillation. It was not hoped or intended, therefore, that this paper would "fill a long felt want," but merely that it would throw some additional light on a phase of the gas business which has usually been considered from another angle and subordinate to the principal object.

Within the last few years, however, rapidly changing conditions have caused considerably more attention to be given to the economical and complete recovery of these substances and it is perhaps not an unsafe prediction to make,—in these days of rate regulation and high cost of raw material,—that these by-products of the gas industry, now steadily increasing in importance and value, will become the hope and stay of the business, and that the field of their recovery and exploitation will be a fruitful one for the exercise of the inventive skill and business acumen of the gas engineers and chemists of to-morrow.

The author wishes to express his indebtedness to Mr. George H. Cushing, editor of *The Black Diamond*, for permission to reproduce Figure 1; to The Western Gas and Construction Company, The Gas Machinery Company, The Improved Equipment Company, The Isbell-Porter Company, The Lloyd Construction Company, The Koppers Company, The American Gas Institute, and to Mr. W. L. Rowland for other illustrative material.

Refractory Materials for Gas Retorts. F. J. BYWATER. (*J. Gas Lighting*, cxxvi, 899.)—*Silica Retorts.*—These have been used recently in America with satisfactory results. The retorts were made from crushed ganister quartz (95 per cent. SiO_2), with 2 per cent. milk of lime as the binding medium. They were of D-section, and were built up from bricks and tiles. The expansion on heating was from ⅛ to 3/16 inch per foot, and was allowed for by making the joints either with thick paper or straw-board, which burned away, leaving a thin carbon joint, or with cement consisting of mild aluminous clay, which shrank when heated. The mouthpiece ends of the retorts were made of solid moulded fireclay so as not to crack when cooled by the opening of the lid. The retorts were used with various types of hydraulic discharging machines. In some cases less carbon was formed on the inside of the silica retorts and the surface became glazed, facilitating discharge by pushers. The life of the retorts was 3½ to 4 years. The thermal conductivity was greater than with clay retorts, the fuel consumption was less, and the output greater, owing to the shorter period required for burning off the charge.

Testing Refractory Materials under Load.—The melting-point of various clays used in the manufacture of firebrick and retort material was found to be 200° to 320° C. lower when the clay was under pressures of 54 to 112 pounds per square inch.

Flameless Incandescent Surface Combustion. H. H. GRAY. (*J. Gas Lighting*, cxxvi, 786.)—The author criticises the view that surface combustion consists in a catalytic action of the incandescent surface and that the combustion takes place in molecular layers in contact with the surface. The size of a gas flame is reduced by increased aëration, and depends upon the time required for the gas and the oxygen to mix and burn. The absence of flame when a mixture of gas and air is brought into contact with an incandescent surface is, therefore, to be expected. The process occurring in the tube of a Bonecourt boiler is considered to be a modified detonation in which the propagation of the combustion through the gaseous mixture is effected by the incandescent solid instead of by the adiabatic compression of a detonation wave. The setting up of a detonation wave is prevented by the rapid flow of gases in the opposite direction and by the baffling effect of the solid material.

Action of Weak Acids on Soluble Fluorides. P. A. E. RICHARDS. (*Analyst*, xxxix, 248.)—Lactic, butyric, tartaric, malic, citric, formic, salicylic, and benzoic acids all liberate hydrofluoric acid from potassium and sodium fluorides, even with 1 per cent. acid solutions. Carbon dioxide also liberates the hydrofluoric acid from these fluorides, but none of the acids mentioned attacked calcium fluoride.

SEWAGE TREATMENT.*

BY

RUDOLPH HERING, D.Sc., C.E.,

Member of the Institute.

CHAIRMAN AND GENTLEMEN: The subject on which I was asked to speak to you to-night is the treatment of sewage. Since the introduction of water supplies into cities this subject has become an important one in many cities. The water as it passes through the city receives the dirt, dust, and excremental discharges from our houses and, together with rain-water, also the dirt and dust that has accumulated upon the streets, roofs, etc. We have turned the clean water furnished us into dirty water, then called sewage, which is discharged into sewers and reaches the nearest watercourses and, with them, finally the ocean.

As cities grew and the watercourses were small their water frequently became offensive. The heavier matters were deposited in the streams as sludge and putrefied, while the flowing water was deprived of its dissolved oxygen, and both sludge and water became offensive.

It was later found that diseases were caused by certain bacteria which were discharged from our bodies while sick, and entered the sewers and the streams. Sometimes these germs became free and infected the air, or the polluted water was used in such ways that the germs entered human bodies and made them sick. Gradually, therefore, the sewage question became not only one of convenience of city life but one of health.

The first serious troubles were experienced in England, where the communities are crowded and the rivers are small. England had also been the first country to generally introduce modern water supplies into houses. Many of its rivers soon began to get foul and sometimes dangerous to health. Therefore the subject of sewage collection and disposal received most attention and the first satisfactory solutions in England.

To-day we have reached the conclusion in all civilized countries that it is practicable and economical to collect sewage

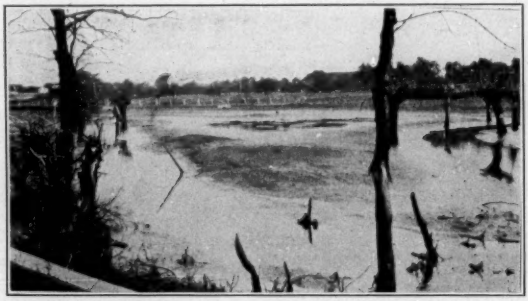
* Presented at the meeting of the Mechanical and Engineering Section, held January 15, 1914.

from houses and cities, and to carry it away underground in sewers, to be delivered either into flowing streams or onto land in such ways that it will neither become a nuisance nor be of any injury to health.

We can now design the house sewers or drains and the receptacles of the waste water in such a way that by cleanliness and proper ventilation we need not have a nuisance in the house nor give disease germs in the sewage an opportunity to enter the same.

We can now design the city sewers in a way so that they can carry the sewage or dirty water from the houses to the out-

FIG. 1.



Poorly-drained land bordering stream in Emscher district of Germany.

falls without causing any nuisance or danger to health on the streets.

There are many cities, particularly in Europe, where there is no offensive odor within the sewers. In Paris, Hamburg, Wiesbaden, and other cities even visitors regularly inspect them who desire the sensation of passing through these waste-water channels under the streets. I feel satisfied that it is only a question of time when in all cities we shall have our sewerage systems so built and maintained that no more offence will arise from them than we now expect in our bathrooms, water-closets, or kitchens.

When the sewage from the house gets into the sewer it consists of liquids and solids. At first nearly all of the matter which is liable to become offensive is in solid form. The sewage can

be strained when leaving a house, and the liquid on standing will rarely, if ever, become foul, because whatever little dissolved organic matter it may contain is oxidized by the large quantities of dissolved oxygen. As the sewage runs on the solid matter is more and more dissolved. After a mile or two, and generally at the outfalls, we find that about one-half of the waste organic matter is in solution. After flowing many miles a still larger part is dissolved.

It is important to realize this last fact, because the question of sewage disposal and treatment is very much dependent upon

FIG. 2.

Land bordering stream in Emscher district of Germany after improvement of stream channel.

the physical condition of the sewage and whether there is much organic matter in solution or not.

The nuisance resulting from sewage is caused by the gradual exhaustion by this matter of the oxygen dissolved in the water. Organic matter as it decomposes first consumes oxygen, and when the latter is all gone an entire change takes place in the process, and hydrogen is then consumed. The first process we call oxidation, and it is entirely inoffensive. The other process we call putrefaction, and it is quite offensive. It is the condition which we have tried to prevent and can now prevent, knowing better than formerly the conditions under which it occurs.

Both oxidation and putrefaction are accomplished by the action of bacteria, which fact, as it concerns sewage, has been

known only for the last thirty or forty years. Since the discovery of bacterial action in converting dead organic into mineral matter we utilize two classes of bacteria for this purpose. One class is that of the aërobic bacteria which cause oxidation in the presence of oxygen; the other class is that of the anaërobic bacteria which live in the absence of oxygen. We are concerned, however, with two orders of anaërobic bacteria. One produces putrefactive or offensive conditions, the other does not. This fact has been applied to sewage treatment only within a few years. The latter kind are not putrefactive; they decompose the

FIG. 3.

Open sewer in Emscher district of Germany.

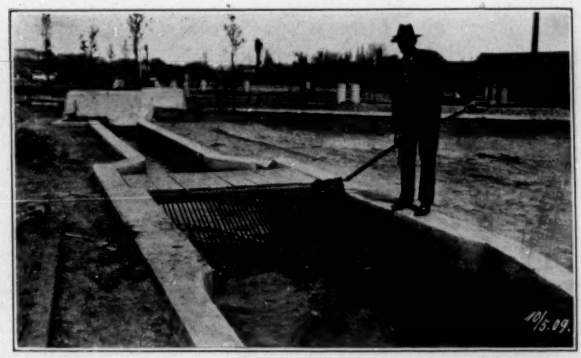
sewage without oxidation and yet do it in an entirely inoffensive way. Offensiveness is caused by the production of bad-smelling gases, of which the principal one is sulphuretted hydrogen. We can now prevent the development of sulphur bacteria, which produce this gas, by creating conditions which allow other bacteria to develop which produce marsh gas and carbon dioxide, neither of which is offensive. In the modern methods of sewage treatment we therefore endeavor to utilize the aërobic bacteria, and, of the anaërobic bacteria, chiefly those which produce marsh gas and carbon dioxide. This practice constitutes the greatest progress we have made in sewage treatment during the last few years.

We can now say that the entire process of sewage collection

and disposal, from start to finish, can be conducted inoffensively. We do not hesitate, as we did less than fifty years ago, to have a bathroom next to our bed- or living-room. The kitchen sink has less odors than formerly. Street sewers in many cities are no longer offensive.

We have not yet advanced as far as this in all street sewers, particularly in our country, because they are not all properly built nor cleaned. The suspended matter carried by the sewage is frequently retained either by deposit or by the roughness of the sewer lining or by eddies formed, where the flow is not

FIG. 4.

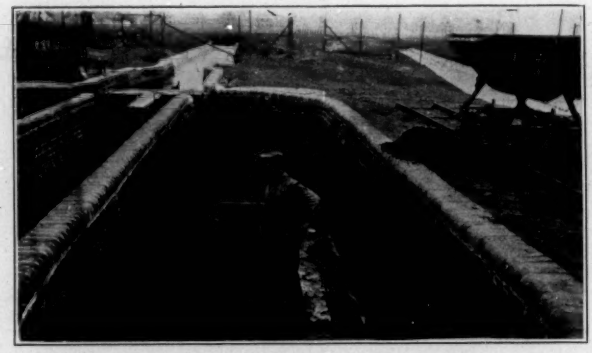


Sewage screen.

regular. In such cases where the retention is more than a day the dissolved oxygen becomes exhausted and putrefaction begins. To prevent this retention the sewage must have a steady and regular flow and rapid velocities, and the interior surface against which the sewage flows must be as smooth as practicable. All the progress in city sewerage that has been made in the last fifty years has been along these lines, so that as a result thereof the sewage not only is devoid of odors in the sewer but is delivered at the outfall with a remnant of dissolved oxygen and without putrefaction. In fairly good sized towns properly sewered and where the sewers are kept clean I have never observed at the outlet anything worse than a stale odor.

To get this result we should also have proper means of flushing the sewers, and also of well ventilating them so that they contain fresh air at all times. The oxygen of the air replenishes what is being exhausted by decomposing matter in the water and by the temporarily stranded matter along the sides. In Europe it is customary to flush the smaller sewers once or twice a week, the larger ones once or twice a month. In our country we do not yet flush the sewers as much as we should, and in most cities the flushing is left to the rain-water which enters occasionally. Rain-water flushing may prevent serious deposits, but it will not pre-

FIG. 5.



Grit chamber during cleaning.

vent temporary deposits which produce the objectionable odors. Small sewers are flushed by automatic flush tanks, which generally keep the smaller sewers in a better condition than the larger ones.

Flushing and ventilating not only prevent nuisance but also help to remove disease germs. Ventilation either tends to desiccate them or to scatter them by dilution to points where they are likely to perish. Flushing carries them away to the outfall. A large number of pathogenic bacteria connected with typhoid fever and diarrhœal diseases are doubtless contained in sewers. Yet careful inquiries made in Europe and here have not resulted in the discovery of a single case of typhoid fever or

dysentery which could be directly traced to sewer air where sewers had been kept clean and fresh.

Sewers were first introduced for the purpose of carrying away rain-water. It was only a second thought to carry away also the waste water from the houses through the introduction of the so-called water-carriage system of sewage removal. The method of uniting the sewage and rain-water in the same channel has caused what is known as the combined system of sewerage.

In recent years it has frequently been found more economical to carry the dirty water or sewage away by a separate system of pipes, and the rain-water by another system. An economy results from the fact that in building up town areas we are generally more concerned at first in removing the dirty house water in pipes than the street water, and are willing to let the latter run off on the surface so long as no trouble is caused thereby. When the latter becomes objectionable, then it often happens that much shorter drains are required, because the rain-water is comparatively clean and can be discharged into any near brook, while the sewage must be carried farther away and perhaps must be treated. Sometimes a city has both systems, as, for instance, your own city of Philadelphia, where the combined system is used for the largest part, but where in the suburbs there are sections where the separate system has been preferred as being less expensive.

The separate system is generally preferred where the sewage must be treated in some way, and where it must be pumped. Should there be a large amount of rain-water mixed with the sewage, the treatment and the pumping become expensive.

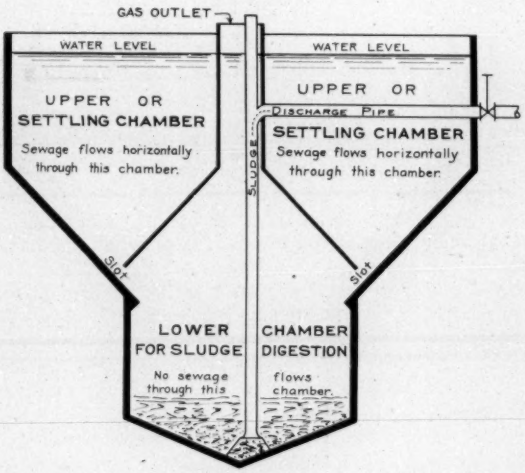
The question has frequently been raised as to whether or not the first flow of the rain-water, which generally carries manure and dust from the streets of a city and a great many bacteria deposited upon the street surface, should be carried into the sewers or kept separate in the storm-water drains. Dr. William Dunbar, of Hamburg, very carefully determined the condition of the street water at the beginning and at the end of a storm. He found that at the beginning the water was as foul as the sewage in the sewers. It is very desirable, therefore, if it can be practically done, that in the case of a separate system the first wash from the streets be taken into the sewers, so that it can be treated with the sewage. This expedient is followed in some

cities in Europe, and I think that in the future it will be followed more frequently in our country than heretofore.

Another most important part of a city sewerage system is the final disposal of the sewage. This should be accomplished in a manner so that it will not be harmful nor unpleasant. We should, therefore, soon determine upon a place of final discharge and a method of treatment to which it should be subjected.

Such a treatment may be complex. We have to consider

FIG. 6.



Vertical section through Imhoff tank at right angles to the direction of sewage flow.

disease germs on account of the danger to health, and the putrefying matter so far as a nuisance is concerned. We have further to distinguish between the most economical ways to prevent both of these troubles.

One part of the sewage is solid matter in suspension, and the other part is liquid matter together with fine suspended matter which will not readily settle out but remains in the liquid and causes it to be more or less turbid.

For the purpose of any subsequent treatment it is best to divide

the sewage into these two parts, because the treatment of the solids demands an entirely different process from that of the liquids.

The first thing to be done, therefore, when sewage is to receive any treatment, is to allow the suspended matter to be held back and separated from the liquid matter, so far as this is practicable.

The collection of the solid matter is accomplished by screens and by sedimentation. Many sewers, when they discharge into rivers, have screens near their outfalls causing the larger matters to be retained, taken out, and separately disposed of. Sometimes

FIG. 7.

Imhoff tanks and sludge-drying beds at Recklinghausen, Germany, population 30,000. Note proximity of dwellings.

this matter is pressed, squeezing out much of the liquid, and the remaining matter is either buried or burned.

Where screening is not adopted there is no way of keeping out the floating matter, except by retaining the sewage in large basins in which the floating matter gathers at the top and from where it can be removed at the surface. The retention of the sewage also causes the heavier matters to deposit.

When the oxygen in the sewage is exhausted the deposited matter or sludge begins to putrefy, and the evolution of gases causes the entire mass of sewage and sludge to become putrescent or septic and emit strong odors. Many studies have been made

and perhaps a hundred patents have been taken out relating to the treatment of this sludge so that the results would be acceptable both from the standpoint of cost and nuisance.

The most common treatment has been to put the sludge upon fields, where it was dried, ploughed in, or covered with lime, etc. It has also been pressed, mixed with strong fertilizers or pulverized and used as manure.

In order to have a more complete removal of the suspended matter from the sewage, lime was added to the water. The resultant sludge, increased in quantity, was then usually dumped or pressed into solid cakes, for use as fertilizer.

FIG. 8.

Imhoff tanks at Essen, Germany, population 180,000. Note proximity of dwellings.

All the processes of treating sludge were, however, not very satisfactory because of the resulting stenches. Yet they had to be recommended as the best known expedients, and on account of the offensive odor it was necessary to locate the treatment works far away from the inhabited parts of the cities. Only a few years ago the city of Baltimore bought a strip of land about 1000 feet wide outside of its works in order to obviate any nuisance.

About eight years ago a German engineer erected some experimental plants at Essen, modelled after the experience gained at the sewage fields near Hampton, England, where Dr. Travis had been making some promising studies. The Essen experi-

ments, undertaken by Dr. Imhoff, resulted in the discovery of a means of securing a collection and a treatment of the sewage sludge that was not offensive.

This process is now known as that of the Imhoff tank treatment. Varying the process from that used at Hampton, by preventing any circulation in that part of the tank where the sludge is deposited and where it ferments, Dr. Imhoff has succeeded in establishing a decomposition confined to the biological action of such classes of bacteria which develop substantially only marsh gas and carbon dioxide gas, neither of which has an odor.

It is known that if no fresh sewage flows over decomposing

FIG. 9.

Sludge dump for dry sludge after removal from drying beds.

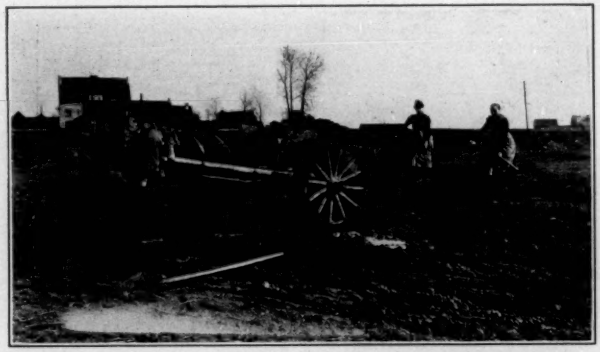
sludge, to supply it with miscellaneous sewage bacteria, the controlling bacteria in the sludge are confined substantially to but two classes; namely, those producing the two inoffensive gases just mentioned.

The Imhoff tank consists of practically two tanks, one over the other. Through the upper one the sewage flows with a velocity reduced so much that its suspended matter will settle. It requires a passage through the tank of from 1½ to 2½ hours. This matter is allowed to slip through a slot into a lower chamber in such a way that no possibility exists for any solid matters to rise and again mix with the fresh sewage passing by in the upper tank. There are special shafts provided for the ascent of

any fat or light matter, which should rise with gas bubbles from the lower chamber, and to form a scum in the shaft, to be removed when necessary. This scum is usually small in amount and could be readily removed if it becomes excessive. It has no objectionable odor in any of the existing plants (see Fig. 6).

The accumulating sludge in the lower tank, when it has become ripe and the existing sulphur bacteria have been practically exterminated, has no odor. This can be found by extracting some of it from different depths. According to the character of the sewage, it requires about three to five months to be de-

FIG. 10.



Dried sludge from Imhoff tanks sold to farmers for fertilizer.

composed sufficiently so that it will not become putrescent when again exposed to the air. The decomposed sludge is withdrawn from the bottom of the tank automatically, and, being deprived of its slimy, putrescible matter, it is friable and porous, looking very much like garden soil, to which it is very similar. The latter has been formed from the leaves and branches without putrefaction and with the evolution of the same inoffensive gases, such as marsh gas and carbon dioxide, which produces the decomposition in the Imhoff tanks. It rapidly drains out its superfluous water, and dries in well-drained beds within a week sufficiently to be spaded and removed.

There are over 100 plants in operation in Germany and this

country, and reports indicate that in none of them which are properly operated does the sludge have an offensive odor. In our country the largest plant is in Atlanta, Ga., and there is one at Holmesburg, Philadelphia, below the Torresdale Water Filtration Plant.

It is gratifying, therefore, that we have now a means of treating the sludge so that it will not be offensive, and we believe that by the same process the disease germs contained in the sludge will have perished by the time it is extracted and dried.

Before sewage reaches the tanks it is advisable, particularly where the sewage contains street wash, to take out any gravel or sand (*i.e.*, grit). This deposition is secured in a special small chamber where the velocity of the sewage is reduced to about 12 inches in a second. This reduction will cause the grit to deposit and the rest of the suspended matter, which contains the foul matter, to pass on to the settling chambers. In these tanks the velocity is much more reduced, generally to about one-tenth inch per second. This comparatively quiescent state causes the deposition of practically all of the foul suspended matter which forms the bulk of the sludge. We use the term "settleable" matter because there is not deposited the fine suspended matter which may cause putrefaction and which must be treated together with the dissolved organic matter.

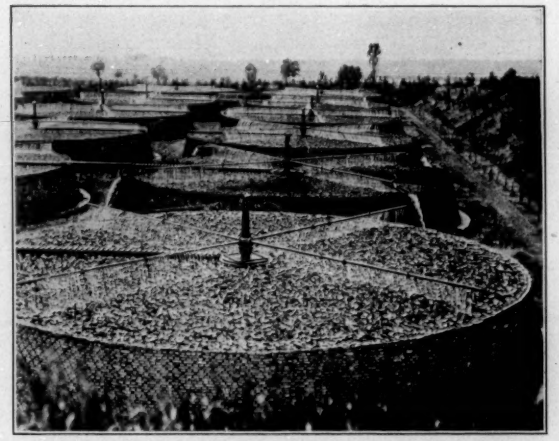
In order to increase the quantity of settleable sludge, experience has shown that by adding a precipitant to the sewage a large percentage of this fine matter and even some of the dissolved matter can be coagulated and also settle into the lower tank. In the latter case the effluent sewage is much clearer, but the size of the lower tank must be correspondingly increased on account of the added sludge and precipitant. It is, of course, a question to be determined in each case as to whether or not it is necessary or wise to add a chemical precipitant.

You have all heard of the septic tank. This was first used under this name in the city of Exeter, England, and it was found that in a single basin where the sewage was retained at least 8 hours most of the suspended matter was deposited on the bottom and underwent putrefaction. It was allowed to remain in the tank until fairly well rotted out, which generally took at least a year.

This was a process of putrefaction which produced chiefly

sulphuretted hydrogen, and, therefore, not only the liquid but also the putrefying sludge sent up bubbles of offensive gas. Notwithstanding this fact, septic tanks have been very extensively used on account of their relative economy as compared to other processes, and it was even heralded as the long-expected final solution of the sludge question. A good deal of the sludge disappeared, so that in a few cases but 10 per cent. of the original quantity was left; in most cases the record is from 25 to 50

FIG. 11.



Revolving sprinkling filters at Wilmersdorf, Germany.

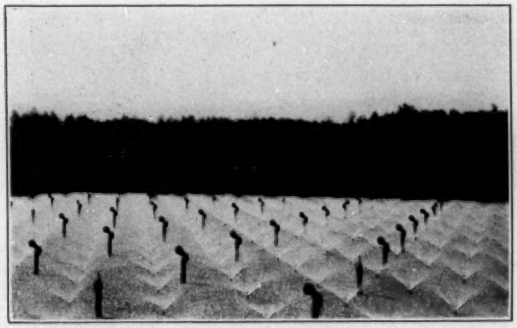
per cent. The reduction in the quantity of sludge handling was the chief attraction of this process.

On account of the odor septic tanks were isolated and kept far away from inhabited sections of a city. In the city of Saratoga, N. Y., there is a well-devised system of sewers and of sewage treatment, with possibly the best instalment of a septic tank in this country. The odor from the tank, however, is very strong. In one of the suburbs of Berlin (namely, Wilmersdorf) septic tanks are also used with very similar results. The odor from the tanks was found to be perceptible over a mile away.

We cannot place much reliance on the figures given as to the reduction of the sludge, because so much depends upon the amount of water contained therein. If we have originally 95 per cent. of water in the sludge and reduce the same to 90 per cent. we have diminished the quantity of sludge practically one-half. This fact makes it necessary, when comparing quantities of sludge, to compare also their percentages of water.

The sludge of the septic tank is of a different character from that of the Imhoff tank. It is not as thoroughly decomposed, generally retains a large amount of fine and slimy matter with a

FIG. 12.



Sprinkling filter at Atlanta, Ga.

large amount of water, and after withdrawal does not become spadeable sometimes for several months.

The last subject to be mentioned is the treatment of the liquids after they have been freed from the settleable suspended matter by passing through the tanks. There are still generally left a substantial amount of fine suspended particles and a large amount of dissolved organic matter. The oxygen contained in the water is rapidly extracted.

If the sewage is discharged into a running stream, and if there is enough oxygen in it to oxidize its organic matter, a decomposition of the organic matter will take place in the water. This method of oxidation in running streams is a practicable and legitimate means of oxidizing liquid sewage. It is just as rational

as an oxidation on land. We are, therefore, not justified in seeking the entire exclusion of all sewage from rivers where they can be utilized for oxidation, both economically and without offence.

We must not forget, however, that nuisance is not the only question to be considered. We must prevent also all objection due to the injury of fish and shell fish and to a possible danger from bathing, and in no case can such water, which has received sewage, be used for drinking purposes, unless it is first purified.

FIG. 13.

Intermittent sand filter for sewage at Stockbridge, Mass., showing distributing channels.

We must also not forget that river water may be polluted as much from the natural land washings and city washings during a rain storm as from liquid sewage.

Nearly all of the large cities of the world dispose of their sewage by river dilution. In some cases this process is not properly carried out: the solid matter of sewage is admitted in too large proportions, and sludge remains in the rivers by sedimentation. Sometimes, also, more liquid sewage is discharged than can be properly oxidized by the water. Yet, after the floating

matter and sludge have been removed, before sewage is discharged into a river, and if the river contains enough oxygen, there can be no objection to utilizing nature's means of purifying organic waste matter in this very economical way.

If there is no river, or if the river is not large enough to promptly dilute the amount of sewage in question, and if there is trouble anticipated regarding fish life, then it is necessary to purify some and often all of the sewage on land.

There are many processes of such purification on land which have been tried, particularly in England. It will not be necessary to mention them all, because most of them have been abandoned. To-day there are really but two processes in use: a treatment by coarse-grained filters and a treatment by sand filtration.

The coarse-grained filters are built of material from the size of a walnut to the size of a fist, and of depths varying from 5 to 10 feet. The sewage is delivered upon the top in various ways. In all cases it must be sprinkled either from stationary or movable jets, because otherwise the large pores of the bed would let it rapidly run through. The sewage percolates through the bed by slowly flowing on the surfaces of the grains from one to the other until it reaches the bottom. Upon these grains or stones is a slimy coating which harbors myriads of bacteria. These take from the passing sewage the organic matter which is in solution and convert it into inoffensive and inert matter. While the water may be quite putrescible when sprinkled on, it leaves the filter, if this is properly devised, without putrescibility; *i.e.*, in a condition so that it will not become foul.

The process of sand filtration is virtually the same as just described. The grains are much smaller and, therefore, the liquid can flow directly upon the bed for distribution instead of being sprinkled. The speed of percolation is much slower and, therefore, the purification is greater. Bacteria do the converting in both cases.

Both coarse- and fine-grained beds are underdrained to allow of a free discharge of the effluent, and both should have a free circulation of air between the grains to supply the oxygen which is necessary to convert organic matter.

(A large number of lantern slides were then shown upon a screen and explained. A few of them are here reproduced with brief explanations.)

Detinning Methods. U. S. CONSUL, GEN. R. P. SKINNER, Berlin. (*The Metal Ind.*, xii, No. 8, 326.)—The recovery of tin from tin-plate waste has recently gained great importance. There are three general methods of separation—mechanical, chemical, and electrolytic. In the mechanical process, which gives only poor results, the tin is melted or thrown off during heating. In chemical separation the tin-plate waste is treated at a low temperature with dilute hydrochloric, nitric, or sulphuric acid, and the tin and zinc are dissolved. The most important method is the electrolytic. As a rule, the electrolyte is hot caustic soda, 6 to 7 per cent. Na_2O. Loose chips of tin packed in wire baskets are the anodes, while the iron bath walls, or iron plates suspended therein, serve as cathodes. The average tension is 1.5 volts. The separated tin is spongiform. Another process has an acid electrolyte, 1 volume of 60 per cent. sulphuric acid to 9 volumes of water. Chips of tin plate in wooden latticed baskets serve as anodes, and tinned copper as cathodes. The density of current is about 100 ampéres to the square metre. The electrolytic methods using acid and ferrosulphate electrolytes have not shown any practical value The greatest amount of tin-plate waste is detinned by the chloride method of Lambotte, of Brussels. The principal requirements for a successful application of this method are absolute exclusion of moisture during the process of detinning, avoidance of an unduly high temperature, and proper washing of the detinned waste. Lambotte's method is described in Imperial German letters patent No. 32517.

The Melting-point of Arsenic. W. HEIKE. (*Int. Zeits. Metallog.*, vi, 168.)—Heating and cooling curves of arsenic contained in an exhausted porcelain vessel packed in sand in an iron bomb gave a melting-point of 830° C. No other thermal effects were noted between 150° C. and this temperature. The arsenic, after being melted, was steel-gray to lead-gray in color; it was very brittle and broke easily with a brilliant fracture; the hardness on Moh's scale was 3½ to 4.

Light from Unconsumed Electrodes. A. VOSMAER. (*Met. and Chem. Eng.*, xii, 377.)—If the discharge from a Ruhmkorff induction coil equipped with a modern Wagner hammer be made to pass between two nickel wires about 2 mm. apart, the ends will burn and form globules. If now the distance is increased to 3 to 4 mm., the wires will continue glowing without further adjustment. No oxidation or vaporization takes place, as the distance between the wires remains the same, and spectroscopic examination shows a continuous spectrum without lines. Platinum wires melt rapidly under the same conditions. If a copper wire is substituted for one of the nickel wires, the nickel electrode glows, while the copper electrode remains dark.

RECENT DEVELOPMENTS IN THE ART OF ILLUMINATION.*

BY

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In the JOURNAL OF THE FRANKLIN INSTITUTE for the last few years there are to be found a number of papers dealing with certain phases of illumination. These are of especial interest to a limited number of Institute members, but most of them are somewhat esoteric and presumably have been read in detail by but a limited number of Institute members. Consideration of the character of the Institute membership has led the writer to feel that he could perhaps be of some service by endeavoring to outline in a comprehensive way the nature and scope of the art of illumination and by making available a brief review of developments in illumination which will place before the members a general view of the subject in its large features. Accordingly, this paper will be found to contain but little of new interest for the illuminating engineer, being written more especially for the consideration of the membership of the Institute at large.

In the discussion which follows a fragmentary bibliography is included. The references which are noted are intended to direct attention to significant papers, and to furnish an indication of the manner in which the several phases of each division of the subject of illumination are being developed.

Illuminating engineering as a distinct specialty is perhaps not generally understood. The name illuminating engineering as applied to this specialty is perhaps not wisely chosen. It will serve, however, for the purpose of this discussion. Illuminating engineering, then, as a specialty may be represented by the diagram in Fig. 1.

The specialist applies the materials of illumination with the aid of the science of illumination, and practises the art of illumination.

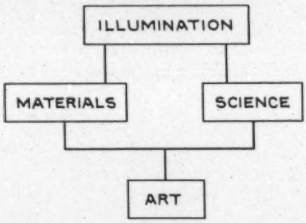
* Presented at a joint meeting of the Electrical Section and the Illuminating Engineering Society, held Thursday, April 9, 1914.

THE MATERIALS OF ILLUMINATION.

The *materials of illumination* may be classified as illuminants —natural and artificial—lighting auxiliaries, and fixtures.

Considering first *incandescent electric lamps*,[1] it may be noted that increases in the efficiency of light production have been ac-

FIG. 1.



companied by increase in the variety of illuminants both as to types and sizes. Neglecting for the moment other qualities than the efficiency of light production, your attention is directed to the

FIG. 2.

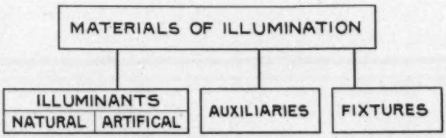


diagram in Fig. 3. This shows improvements in incandescent electric lamps which were made available some years ago and the status of lamps of more recent development. It will be noted that the advances in the efficiency of light production have been

[1] *Incandescent Lamps:*

"A New Carbon Filament," Howell, *Trans. A. I. E. E.*, 1905, p. 839.

"New Types of Incandescent Lamps," Sharp, *Trans. A. I. E. E.*, 1906, p. 815.

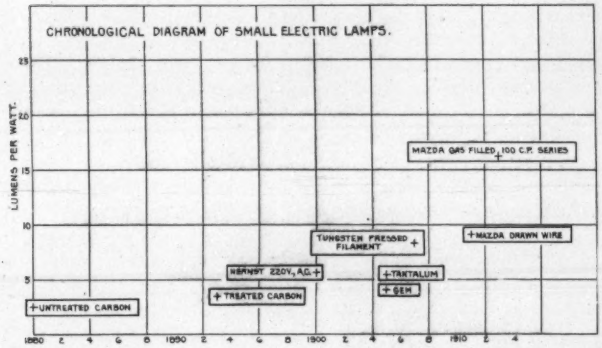
"High Efficiency Lamps," Doane, *Proceedings N. E. L. A.*, 1910.

"Recent Progress in the Art of Lamp Making," Randall, *N. E. L. A.*, 1913.

"Tungsten Lamps of High Efficiency," Langmuir & Orange, *Trans. A. I. E. E.*, 1913, p. 1915.

marked. The carbon filament lamp which had remained without material efficiency improvement from 1893 to 1905 was at that time improved through the development of the so-called "metallized" carbon filament, and in that form remains the most efficient type of carbon filament incandescent lamp. The carbon filament lamp had been the standard form for general electric lighting, and continued to be the standard lamp and the most largely produced lamp until about 1912. Its preëminence was challenged before that time because of the adoption of the metallized carbon filament lamp for free renewal to customers by the

FIG. 3.



larger central stations of the country, and was lost in 1912 as a result of the influence of lamp manufacturers in promoting the sale of the metallized filament rather than the sale of the carbon filament lamp. The substitution of the metallized carbon filament lamp for the earlier form of carbon filament lamp resulted in an increase of the standard of illumination throughout the country, for it consumed the same energy and produced about 20 per cent. more light than did the earlier carbon filament lamp.

In 1905 the various forms of carbon filament lamps were supplemented by the tantalum lamp, an importation from Europe. This lamp never entered largely into American practice, its largest sale in the country probably never exceeding 3 per cent. of the total sales of incandescent lamps. Its inferiority when operated

upon alternating current and the announcement of the invention of the tungsten lamp shortly after its appearance, prevented its attaining a position of importance in our practice.

The tungsten filament lamp, first made available commercially in 1907, was a marked improvement over other lamps then available, although its fragility and relatively high price led to restriction of its use in the earlier years of its history. Through the splendid development work of American lamp manufacturers, this lamp has been rendered much more effective in all respects than it was a few years ago. The substitution of the drawn wire mounted as a continuous filament placed the lamp in a class with the carbon filament lamp in respect to ruggedness. The development of bulb blackening preventives has permitted its operation at somewhat higher efficiencies. These improvements, with notable price reductions, have led to the large use of the tungsten, now known chiefly as the Mazda lamp, so that in 1913 sales of the Mazda lamp exceeded sales of all other types of incandescent electric lamps, notwithstanding the fact that the life standard which it sets is twice that which obtained previously.

During the past year, a new form of tungsten filament lamp has been announced, in which the bulb contains an inert gas which reduces the rate of evaporation of the filament and permits operation of the lamp at a higher efficiency. This gas-filled Mazda lamp is chiefly of importance in the larger sizes, and in effect creates a new lamp of characteristics similar to the incandescent lamp but of power equivalent to the arc lamp. In its smaller sizes it is included on the diagram, marking the highest efficiency attainment in the production of light by small incandescent lamps.

The Nernst lamp was brought to its highest development in 1908 in the Westinghouse Nernst. Its active exploitation practically ceased in 1912, due to the superior qualities of the tungsten filament lamps.

Paralleling the improvement in efficiency of light production by means of incandescent lamps have come improvements in *larger electric illuminants.*[2] The pure carbon open arc lamp was

[2] *Arc Lamps:*

"The Invention of the Enclosed Arc Lamp," Marks, *The Sibley Journal of Engineering*, October, 1907.

"Properties and Industrial Applications of the Flame Arc Lamp," Blondel, International Electrical Congress, 1904, vol. 2, p. 729.

supplemented in about 1893 by the enclosed carbon lamp, which largely supplanted it in spite of a lower efficiency because of more desirable operating characteristics. This enclosed carbon arc lamp has been for a number of years the standard street lighting illuminant of America, and only within the past two or three years has yielded its position of preëminence in that field to the newer and superior forms of arc lamps. The intensified carbon arc lamp has found considerable application in the lighting of interiors, principally stores. In this lamp pure carbons of relatively small diameter are operated at high current density within a globe which partially restricts the air supply. The resultant light is more nearly white than that usually obtained from the carbon arc lamp and offers some advantages for store lighting purposes.

The metallic electrode arc lamp, of which the Magnetite and Metallic Flame lamps are the principal examples, has come into large use in street lighting and more than any other type of lamp has supplanted the enclosed carbon arc lamp. This lamp differs radically from earlier forms of arc lamps in that the light is produced by luminescence and emanates wholly from the arc stream, whereas in the several forms of pure carbon arc lamps the light is produced by incandescence of the electrode ends.

The flame arc lamp (short life form) is the highest achievement in efficiency of light production among commercial electric illuminants. In its earlier forms it suffered from short electrode life, which made its operation costly and practically limited its usefulness in this country to display lighting. In repetition of the history of the pure carbon arc lamp, the flame arc lamp, which is equipped with carbons impregnated with various salts, has been adapted to secure long electrode life by partially enclosing the arc and employing large diameter electrodes. As in the earlier lamp, this operating advantage has been secured at the expense of loss

"The Electric Arc," Steinmetz, International Electrical Congress, vol. 2, p. 710.

"The Metallic Flame Arc Lamp," Stephens, *Trans. Illg. Eng. Soc.*, 1907, p. 657.

"Design of Luminous Arc Lamps," Halvorson, *General Elec. Review*, 1911, p. 578.

"Arc Lighting," Steinmetz, *General Elec. Review*, p. 568, 1911.

"Ornamental Luminous Arc Lighting at New Haven," Halvorson, *General Elec. Review*, 1912, p. 220.

"Enclosed Flame Arc Lamp," Chamberlain, *General Elec. Review*, 1912, p. 706.

in efficiency, and the long-burning flame arc lamp is not to be confused with the more efficient short-life flame arc lamp in this respect.

The gas-filled Mazda lamp,[3] small sizes of which have been included in consideration of incandescent lamps, has not yet emerged from the developmental stage, but is known to be among the very highest efficiency electric illuminants, especially in its larger sizes.

The mercury arc lamp is available in two types. The low-pressure arc in glass tubes is the earlier form and is in more general use than the high-pressure quartz tube lamp. The latter, however, surpasses it in efficiency.[4]

The Moore tube, filled with nitrogen for general illumination purposes, has been used to a limited extent for special classes of lighting. Smaller sizes in which carbon dioxide replaces nitrogen are used only as artificial daylight.

The Neon tube, as devised by Claude of France, marks a distinct advance in the efficiency of tube lighting. Whereas the Moore nitrogen-filled tube yields light of a pinkish-yellow tinge, the Neon tube gives light which is red.[5]

The diagram, Fig. 4, summarizes and compares the light-producing efficiency of these several large illuminants. The enclosed carbon arc lamps and the Moore tube are the lowest in efficiency. The 4-ampère Magnetite lamp is of substantially the same efficiency as the old open carbon arc lamp. The 6.6-ampère Magnetite and the low-pressure mercury vapor lamp are next in order, just failing to reach the efficiency of the long-burning flame arc lamp, of the quartz high-pressure mercury vapor lamp, and the Mazda gas-filled lamp. A short-burning flame arc lamp producing 36 lumens per watt is distinctly the most efficient of these large illuminants.

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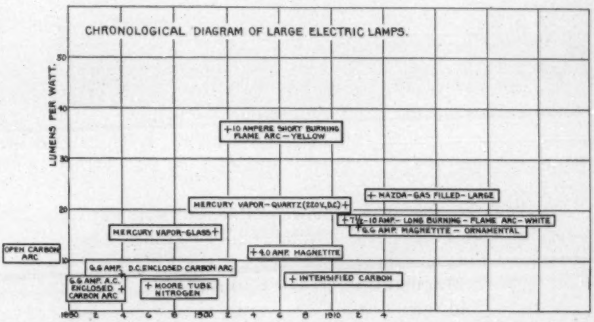
[3] *Mazda Gas-Filled Lamps:*
"Tungsten Lamps of High Frequency," Langmuir and Orange, *Trans. A. I. E. E.*, 1913, p. 1915.

[4] *Mercury Vapor Lamps:*
"Notes on the Cooper-Hewitt Lamp," Cooper-Hewitt, *Elec. World and Engineer*, 1910, p. 679.

[5] *Tube Lighting:*
"Light from Gaseous Conductors within Glass Tubes," Moore, *Trans. A. I. E. E.*, 1907, p. 605.
"*Neon Tube Lighting*," Claude, *Trans. Illg. Eng. Soc.*, 1913, p. 371.

The development of the *gas mantle* by Von Welsbach, in 1884, was the beginning of a new era in gas lighting.[6] When the mantle burner was introduced, there were available the flat flame burner, producing 1 to 2 candlepower per cubic foot of 16-c.p. coal gas; the Argand burner, producing perhaps 3 candlepower per cubic foot; the regenerative burners producing as much as 7 to 10 candlepower. The Welsbach lamp made available at first 10 and later something like 15 candlepower per cubic foot of gas. Since the early developments of the modern Welsbach lamp in say 1891, no material improvements have been made in the effi-

FIG. 4.

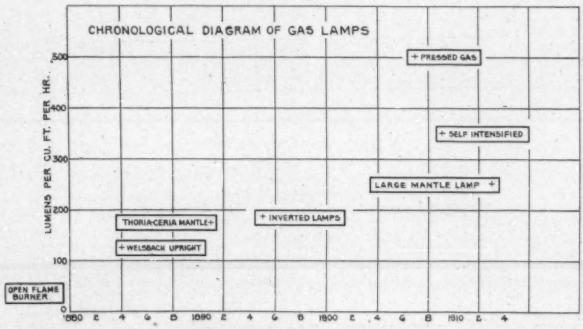

CHRONOLOGICAL DIAGRAM OF LARGE ELECTRIC LAMPS.
LUMENS PER WATT.
50
40
30
20
10
+10 AMPERE SHORT BURNING FLAME ARC – YELLOW
MERCURY VAPOR – QUARTZ (220 V. D.C.) +
+ NAZDA – GAS FILLED – LARGE
+ 7½ – 10 AMP. – LONG BURNING – FLAME ARC – WHITE
7.5 AMP. MAGNETITE – ORNAMENTAL
MERCURY VAPOR – GLASS +
OPEN CARBON ARC
4.0 AMP. MAGNETITE
9.6 AMP. D.C. ENCLOSED CARBON ARC
6.6 AMP. A.C. ENCLOSED CARBON ARC
+ MOORE TUBE NITROGEN
+ INTENSIFIED CARBON
1890 E 4 6 8 1900 2 4 6 8 1910 E 4

ciency of light production from small mantle burners, though burners, mantles and auxiliaries have been further developed along lines which make for better operating qualities. Beginning with about 1901, the number of sizes of lamps employing mantles was increased and the production of an inverted burner was undertaken. By 1906 the inverted burner had attained a point of commercial success, and there had been produced a variety of sizes of upright mantle lamps, ranging from those consuming 1¼ cubic feet of gas up to the multiple burner lamps employed for lighting

[6] *Gas Lamps:*
"Inverted Gas Lighting," Whitaker, *Trans. Illg. Eng. Soc.*, 1907, p. 764.
"Modern Gas Lighting Conveniences," Litle, *Trans. Illg. Eng. Soc.*, 1908, p. 418.
"Symposium on High-Pressure Gas Lighting," Goodenough, Klatte and Zeek, *Trans. Illg. Eng. Soc.*, 1912, p. 506.

large areas, and consuming 12 to 18 cubic feet of gas per hour. Since that time this range of lamps has been realized in the inverted type and various improvements have been made in structural features and operating qualities. Regenerative lamps have been produced and have entered to a limited extent into service in this country. These attain efficiencies of the order of 28 candlepower per cubic foot per hour. Highest efficiencies from illuminating gas have been obtained by the use of pressed gas systems, used largely abroad for street lighting, but not as yet introduced extensively in this country. These yield light-producing efficiencies of the order of 35 candlepower per cubic foot per hour.

FIG. 5.



The progress in efficiency of light production indicated by the record of the manufacturer of gas illuminants is shown in Fig. 5.

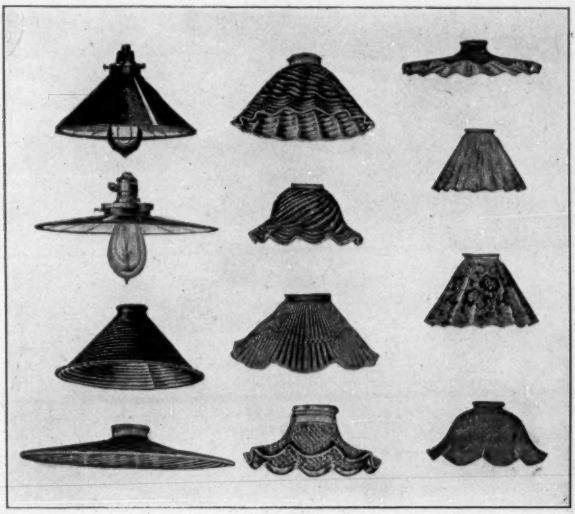
Among *other illuminants*[7] the kerosene oil lamp is, of course, the most important. Its earlier form was improved by the substitution of a round wick, centre draught lamp for the flat wick burner. The incandescent mantle has been applied to the kerosene lamp but without such success as to command general substitution in oil-lamp lighting. Acetylene lighting, filling a limited part of the general illumination field, is not understood to be making any considerable advance in efficiency of light production. The same is true of gasoline lighting.

[7] *Miscellaneous Illuminants:*

"The Progress of the Gas Industry," Morrison, *Trans. Illg. Eng. Soc.*, 1909, p. 36.

One illuminant has been produced which yields light of a color closely approximating what may be considered to be average daylight. That is the Moore carbon-dioxide tube. Mazda lamps, the intensified carbon arc lamp, and gas mantle lamps have been equipped with color screens intended to modify the light to pro-

FIG. 6.



Reflectors of a decade ago.

duce artificial daylight.[8] Some of these duplications of natural light are excellent and are being employed with good effect for commercial purposes. Other illuminants or equipments for illu-

[8] *Artificial Daylight Illuminants:*

"A Standard for Color Values—The White Moore Light," Moore, *Trans. Illg. Eng. Soc.*, 1910, p. 209.

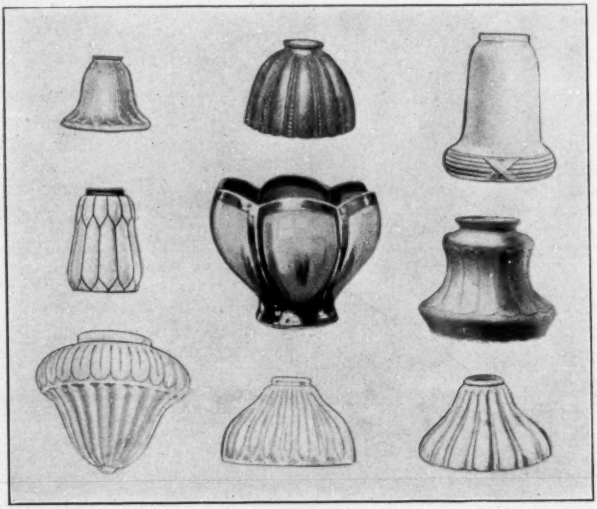
"A Lamp for Artificial Daylight," Hussey, *Trans. Illg. Eng. Soc.*, 1912, p. 73.

"Subtractive Production of Artificial Daylight," Ives and Luckiesch, *Electrical World*, 1911, p. 1092.

"A Gas Artificial Daylight," Ives and Brady, *Lighting Journal*, 1913, p. 131.

minants have been announced as the equivalent of daylight or as having daylight qualities. Unfortunately, however, there has been much misrepresentation connected with this, and so far as the writer is aware, only the efforts named above should be regarded seriously in this connection.

FIG. 7.



Various forms of modern reflectors and globes.

Lighting auxiliaries,[9] including reflectors, globes, shades, etc., have been greatly improved in recent years. Fig. 6 illustrates some types of reflectors typical of those which were sold 10 to 15

[9] *Auxiliaries:*

"The Principles of Shades and Reflectors," Bell, *Trans. Illg. Eng. Soc.*, 1909, p. 723.

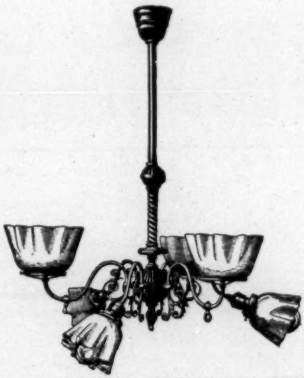
"Scientific Principles of Globes and Reflectors," Lansingh, *Trans. Illg. Eng. Soc.*, 1910, p. 49.

"Symposium on Illuminating Glassware," Jones, Marshall, Young and Hibben, *Trans. Illg. Eng. Soc.*, 1911, p. 854.

years ago. Fig. 7 shows an assortment of modern reflectors which surpass those previously available in appearance, and in that they conceal the light source and diffuse the light. They excel also in efficiency of light redirection.

The design and manufacture of *fixtures* [10] may be divided into two classes; namely, fixtures of distinctive design and stock fixtures. The former cannot well be generalized; the latter, which, of course, are more largely used, have been improved somewhat with the improvement in taste in regard to design which is grad-

FIG. 8.



Typical stock fixtures of a decade ago.

ually being wrought among the public at large. At least, it may be said, that the atrocious fixtures which were placed in moderate priced houses twenty years or so ago are now supplanted by more tasteful fixtures.

Fig. 8 shows a cluster of electric lamps which is typical of those sold ten years ago. Contrast them with the view in Fig. 9

[10] *Fixtures:*

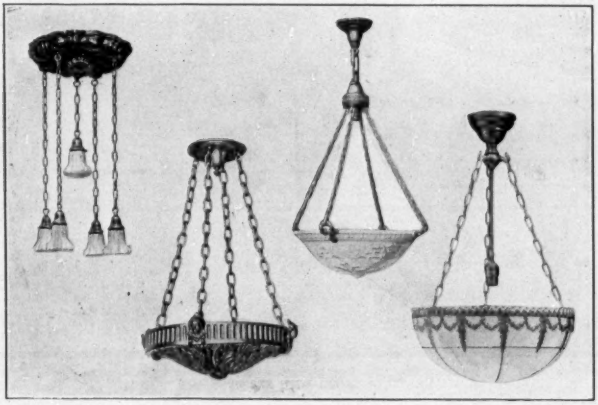
"Fixture Design," Lansingh and Heck, *Trans. Illg. Eng. Soc.*, 1907, pp. 728–784.

"The Relation of Fixture Design to Modern Illuminating Practice," Hopton and Watkins, *Trans. Illg. Eng. Soc.*, 1910, p. 310.

of modern fixtures designed for the same class of use. The latter are superior in almost every respect, and while possibly more costly, yield a much better service return upon the investment.

It is thus apparent that progress in recent years in the design and construction of materials of illumination has been rapid, and that the report of recent developments must be considered to be

FIG. 9.



Modern fixtures.

encouraging in so far as the materials of illumination are concerned.

THE SCIENCE OF ILLUMINATION.

The *science* of illumination may be considered to comprehend engineering, vision, and æsthetics.

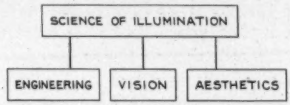
Principles of Engineering.—Considering first the principles of engineering in so far as they form a part of the science of illumination, it may be said that the subject of *supply* falls properly under the headings of electrical or gas engineering. The lighting practitioner must have a working knowledge of usual systems of supply, but no special knowledge is essential.

In the matter of *installation* [11] the practitioner needs to be somewhat more skilled. The electrical contractor, plumber, etc., are prepared to handle installations effectively, but are in need of guidance of the illuminating expert; hence, the latter requires a good working knowledge of the subject.

A thorough knowledge of the design, construction, lighting qualities, and operating characteristics of *artificial illuminants* is essential, and this subject has not been neglected in the literature of the art. *Daylight* [12] also has been studied as to direction, diffusion, intensity, color, etc. Very complete information regarding sources of illumination is thus available to the practitioner.

The study of *auxiliaries* from the several viewpoints of light distribution, light absorption, color modification, dust depreciation, etc., has been an important part of recent developments in the field of illumination. The light distribution curve has become a familiar part of manufacturers' data and has been influential in emphasizing the importance of correct design and low light absorbing qualities for reflectors and globes. It has been shown that there have been marked improvements in the design of lighting auxiliaries. Likewise, there has been a notable growth in the knowledge of the use of such devices and in the discriminating selection of the best available for given purposes.

FIG. 10.



[11] *Operating Characteristics of Illuminants:*

"Deterioration of Gas Lighting Units in Service," Pierce, *Trans. Illg. Eng. Soc.*, 1912, p. 677.

"The Relation of the Incandescent Lamp to the Lighting Service," Cooper and Campbell, *National Elec. Light Assn.*, 1913, p. 400.

"The Proper Lamp for a Circuit," Campbell and Cooper, *N. E. L. A.*, 1912, vol. 3, p. 338.

[12] *Daylight:*

"Daylight Illumination," Marsh, *Trans. Illg. Eng. Soc.*, 1908, p. 224.

"The Intensity of Natural Illumination Throughout the Day," Lewinson, *Trans. Illg. Eng. Soc.*, 1908, p. 482.

"The Distribution of Luminosity in Nature," *Trans. Illg. Eng. Soc.*, 1911, p. 687.

"Daylight," Nichols, JOURNAL OF THE FRANKLIN INSTITUTE, 1912, p. 315.

The literature of the art is rich in discussions of the *physics*[13] of light production, optical principles, color, etc. Knowledge of these subjects has been distributed rather rapidly through numerous presentations before organizations of men interested in lighting.

In the *measurement of light* notable progress has been made in recent years. The measurement of total flux and light distribution in the laboratory and the measurement of illumination intensity and brightness in lighting installations has been developed and now forms a standard part of illuminating engineering practice.

Beyond the introduction of certain refinements which have promoted accuracy of results, there have been no important developments in the practice of commercial photometry during recent years. Probably the most important development in this field has been the reduction in the size of photometers, which has resulted in making *portable photometers* available for the study of illumination. A recent broadening of the scope of such study has included the measurement of brightness as an important branch of photometry.[14]

[13] *Physics and Chemistry:*

"Transformation of Electric Power into Light," Steinmetz, *Trans. A. I. E. E.*, 1906, p. 789.

"Color Values of Artificial Lamps," Stickney, *Trans. Illg. Eng. Soc.*, 1907, p. 282.

"The Theory of Flame and Incandescent Mantle Luminosity," Fulweiler, *Trans. Illg. Eng. Soc.*, 1909, p. 635.

"Luminous Efficiency," *Trans. Illg. Eng. Soc.*, 1910, p. 113.

"Some Chemistry of Light," Whitney, *General Elec. Review*, 1910, p. 101.

[14] *Photometry:*

"The Integrating Photometer," Matthews, *Trans. A. I. E. E.*, 1902, p. 39.

"Illumination Photometers and Their Use, Millar, *Trans. Illg. Eng. Soc.*, 1907, p. 548.

"A New Universal Photometer," Sharp and Millar, *Elec. World*, 1908, p. 181.

"The Integrating Sphere in Industrial Photometry," Sharp and Millar, *Trans. Illg. Eng. Soc.*, 1908, p. 502.

"Color Measurements of Illuminants," Ives, *Trans. Illg. Eng. Soc.*, 1910, p. 189.

"Illumination Tests," Sharp and Millar, *Trans. Illg. Eng. Soc.*, 1910, p. 391.

"Photometry of Large Light Sources," Stickney and Rose, *Trans. Illg. Eng. Soc.*, 1911, p. 641.

"Photometry at Very Low Intensities," Bell, *Trans. Illg. Eng. Soc.*, 1911, p. 671.

A number of investigators are engaged in the study of the problem of *photometry by non-ocular means.* The thermopile and the photo-electric cell with possibly some alternatives are looked to for assistance in the future. While nothing of commercial practicability has yet demonstrated its value, progress is being made.

The variety of color values of the several important illuminants and the other color values which for scientific purposes must be measured, create a requirement for standards of light of several widely different color values. There is a great need for a series of such standards which shall be authoritative by reason of the auspices under which they have been derived as well as by official designation. A number of laboratories are engaged in the study of this problem of heterochromatic photometry and while concrete results in the establishment of such standards are not available yet, progress must be recorded in that the need for such standards is now definitely established and work is under way, which should result ultimately in meeting this need. Present indications are that a range of *calibrated color screens* offers a most practical solution of this problem.[15]

Standards of light[16] may be classified as primary, representative, and working standards. Primary standards, or those reproducible from specifications, are at present flame standards, respectively candles, the Hefner lamp and the Pentane lamp. There have been no important developments in the way of primary

[15] *Photometrical Laboratories:*

"Photometrical Laboratories of National Bureau of Standards," Stratton and Rosa, *Trans. A. I. E. E.*, 1905, p. 999.

"A Testing Laboratory in Practical Operation," Sharp, *Trans. A. I. E. E.*, 1905, p. 1051.

"Photometrical Laboratory of the United Gas Improvement Company, Bond, *Trans. Illg. Eng. Soc.*, 1909, p. 619.

"Physical Laboratory of the National Electric Lamp Association," Hyde, *Trans. Illg. Eng. Soc.*, 1909, p. 631.

[16] *Standards of Light:*

"Standards of Light," Nichols, International Electrical Congress, 1904; Steinmetz, *Trans. A. I. E. E.*, 1908, p. 1319.

"Report of the Committee on Nomenclature and Standards, *Trans. Illg. Eng. Soc.*, 1909, p. 520.

"Heterochromatic Photometry and a Primary Standard of Light," Ives, *Trans. Illg. Eng. Soc.*, 1912, p. 376.

standards of light in recent years, although certain means of arriving at a superior primary standard have been suggested and some research work has been done with that end in view. It is generally recognized that none of the existing primary standards of light is entirely satisfactory and that there is need for the development of a new and superior standard. Representative standards have been adopted and the so-called international candle is the official unit of light in England, France, and the United States. It is the result of standardization work of the past few years and the unit is now represented by groups of seasoned, calibrated incandescent electric lamps held at the official laboratories of these three countries. These form a reasonably accurate and safe standard for light of one color value. From them working standards are derived which accurately duplicate the value of the standard lamps and which are now available for general use of all who require them.

A start toward adopting a reasonable system of *units and nomenclature* [17] was made at the Geneva Electrical Congress in 1896. The Committee on Nomenclature and Standards of the Illuminating Engineering Society has been actively engaged in the furthering of this work. That considerable progress has been made will be testified by the several annual reports of the committee to be found in the Transactions of that Society. The subject of nomenclature is especially vexing, and the art is fortunate in having the services of so distinguished a committee to assist in the adoption of sound definitions, symbols, and nomenclature. Pressure is being exerted with a view to the adoption of the metric system and some little progress appears to have been made toward this end.

The principles of physical optics and of magnetic flux underlie many *calculations* [18] made in illuminating practices. Marked im-

[17] *Units and Nomenclature:*

"Reports of the Committee on Nomenclature and Standards, *Trans. Illg. Eng. Soc.*, to date.

"The Concepts and Terminology of Illuminating Engineering," Sharp, *Trans. Illg. Eng. Soc*, 1907, p. 414.

[18] *Calculations:*

"A Rectilinear Graphical Construction of the Spherical Reduction Factor of a Lamp," Kennelly, *Trans. Illg. Eng. Soc.*, 1908, p. 243.

"The Calculation of Illumination by the Flux of Light Method," Cravath and Lansingh, *Trans. Illg. Eng. Soc.*, 1908, p. 518.

petus was given to calculations of illumination by the application of the idea of luminous flux in commercial illumination design. In recent years, the mathematics of the subject have been set forth repeatedly and it may be said that calculations involved in illuminating engineering work are perhaps farther along toward complete development than is any other branch of the subject.

The subject of *costs* [19] is a fundamentally important feature of the science of illumination, and questions of first cost and operating cost, including maintenance and depreciation, must have the careful attention of the practitioner. The literature of this subject is rather meagre, because of the difficulty of generalizing due to the marked influence which local conditions often exercise upon costs and due to the invidious form which cost discussions are likely to take.

So much for the purely engineering aspects of the illuminating art. The engineering features are important, indeed essential, but other aspects are equally so. The subject of *vision* in all its ramifications forms an integral part of the science of illumination, a fact which is being given due recognition. Light must be correct in respect to intensity, direction, diffusion, color, and steadiness; and to the study of these qualities a knowledge of visual processes and methods of perception is essential.[20] Shade perception and visual acuity together with color perception have been

"Calculating and Comparing Lights from Various Sources," Hering, *Trans. Illg. Eng. Soc.*, 1908, p. 645.

"The Law of Conservation as Applied to Illumination Calculations," McAllister, *Trans. Illg. Eng. Soc.*, 1911, p. 703.

[19] *Costs:*

"The Analysis of Performance and Cost Data in Illuminating Engineering," Harrison and Magdsich, *Trans. Illg. Eng. Soc.*, 1911, p. 814.

[20] *Visual Processes:*

"Effects of Light upon the Eye," Seabrook, *Trans. Illg. Eng. Soc.*, 1908, p. 157.

"Eye-Strain and Artificial Illumination," Krawell, *Trans. Illg. Eng. Soc.*, 1908, p. 212.

"Artificial Illumination from a Physiological Point of View," Standish, *Trans. Illg. Eng. Soc.*, 1908, p. 254.

"Eye-Strain," Pyle, *Trans. Illg. Eng. Soc.*, 1909, p. 447.

"Physiological Effects of Radiation," Steinmetz, *Trans. Illg. Eng. Soc.*, 1909, p. 683.

"The Psychology of Light," Woodworth, *Trans, Illg. Eng. Soc.*, 1911, p. 437.

studied and discussed to an extent which begins to make known some of the more important facts pertaining to vision.

In this connection also the subject of *contrast* may be considered. A knowledge of the behavior of the human eye under various conditions of contrast is all essential to the science of illumination. Therefore the study of reflection and absorption of light and of brightness of surfaces is a prominent feature of the most recent advance in the science of illumination. Glare both from light source and from reflecting surfaces is largely a question of contrast and its suppression in order to promote ocular welfare is one of the principal aims of the lighting practitioner to-day.[21] Excessive brightness means excessive contrast with surrounding objects.[22] Sometimes a light source, which is so bright as to occasion discomfort amid dark surroundings, becomes innocuous when amid bright surroundings. The general recognition of the need for contrast limitation has been effective in reducing contrast in the more recent installations.[23]

Glare is intimately connected with diffusion of light. It is a subject to which a great deal of study has been given within the

[21] *Methods of Perception:*
"Some Physiological Factors in Illumination and Photometry," Bell, *Trans. Illg. Eng. Soc.*, June, 1906, p. 3.
"Allowable Amplitudes and Frequencies of Voltage Fluctuations in Incandescent Lamp Work," Ives, *Trans. Illg. Eng. Soc.*, 1909, p. 709.
"Physiological Points Bearing on Glare," Cobb, *Trans. Illg. Eng. Soc.*, 1911, p. 153.
"Notes on Spectral Character of Light upon the Effectiveness of Vision," Luckiesch, *Trans. Illg. Eng. Soc.*, 1912, p. 135.

[22] *Brightness:*
"Intrinsic Brightness of Lighting Sources," Woodwell, *Trans. Illg. Eng. Soc.*, 1908, p. 573.
"The Measurement of Brightness and its Significance," Ives, *Trans. Illg. Eng. Soc.*, Volume 9, No. 3.

[23] *Light Absorption and Reflection Coefficients:*
"Coefficients of Diffuse Reflection," Bell, *Trans. Illg. Eng. Soc.*, 1907, p. 653.
"Some experiments on Reflection from Ceilings, Walls and Floor," Lansingh and Rolph, *Trans. Illg. Eng. Soc.*, 1908, p. 584.
"Effect of the Variation of the Incident Angle on the Coefficient of Diffuse Reflection," Gilpin, *Trans. Illg. Eng. Soc.*, 1910, p. 854.
"Reflection Coefficients," Bauder, *Trans. Illg. Eng. Soc.*, 1911, p. 85.
"Some Reflecting Properties of Painted Interior Walls," Jordan, *Trans. Illg. Eng. Soc.*, 1912, p. 529.

last few years. In a paper before this Institute, Sweet presented the results of some laboratory experiments on the effect of glare due to the presence of a light source within the field of vision. While the conditions which he employed were extreme and the effect was exaggerated beyond that met in practice, yet the consequences experienced in ordinary installations differ from those found in his experiments only in degree. Glare due to exposed light sources means diminished seeing ability, discomfort and possible injury to the eyes. Another effect also known as glare is that attending specular reflection from polished surfaces. This is a subject which has received especial attention during recent years. Glare of this kind is again a matter of excessive contrast. One views the imperfectly reflected image of a light source upon the page of a book, brightness of the image being far in excess of the immediate surroundings and the general surroundings. The same means which are effective in reducing contrasts between the light source and its surroundings are naturally effective in reducing the contrast between the reflected image of the light source and its surroundings. Thus in avoiding glare due to exposed light sources, glare due to specular reflection is likewise avoided.[24]

The engineering aspects, together with those aspects which pertain to vision, in large part constitute the science of illumination. *Æsthetics* as comprehended in the principles of design, ornamentation, and decoration may, in a sense, be grouped under the science of illumination, and to the extent that it is so considered, it is essentially important. Obviously, however, æsthetics is so much a matter of artistic feeling that the entire subject cannot be classed under this heading.[25]

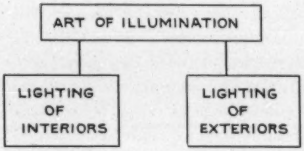
A growing appreciation of the artistic possibilities of lighting

[24] *Contrast, Glare, etc.:*
"Physiological Points Bearing on Glare," Cobb, *Trans. Illg. Eng. Soc.*, 1911, p. 153.
"Artificial Illumination as a Factor in the Production of Ocular Discomfort," Black, *Trans. Illg. Eng. Soc.*, 1911, p. 166.
"The Effectiveness of Light as Influenced by Systems and Surroundings," Cravath, *Trans. Illg. Eng. Soc.*, 1911, p. 782.

[25] *Æsthetics, Architectural Principles, etc.:*
"Electric Light as Related to Architecture," Walker, *Trans. Illg. Eng. Soc.*, 1907, p. 596.
"The Relation of Architectural Principles to Illuminating Engineering," Jones, *Trans. Illg. Eng. Soc.*, 1908, p. 9.

and the growing demand for artistic execution in lighting design are gradually introducing more pleasing features, glassware, and lamps. It is one of the gratifying and encouraging features of the situation that there is nothing inconsistent in the requirements of good illumination whether they be requirements of efficency, ocular hygiene, or æsthetics. It appears that in promoting the one, natural impetus is given to one or both of the others. The more efficient light sources are likely to be more brilliant and to carry with them the need for concealment from view. In meeting this need, design along the lines of least resistance results in dif-

FIG. 11.



fused light from larger areas, forming secondary sources which do not disturb ocular comfort. In the design of such systems of lighting, opportunities for the creation of pleasing and artistic effects thrust themselves upon the designer in a manner which was never encountered when less efficient illuminants of lower brilliancy were placed in rooms without adequate concealment.

The *art* of illumination [26] is the lighting of interiors and of

"Modern Methods of Illumination from the Architectural Standpoint," Castor, *Trans. Illg. Eng. Soc.*, 1908, p. 271.

"The Relation of Illuminating Engineering to Architecture from the Illuminating Engineering Standpoint," Elliot, *Trans. Illg. Eng. Soc.*, 1908, p. 280.

"Architecture and Illumination," Perrot, *Trans. Illg. Eng. Soc.*, 1908, p. 619.

"Illumination and Architecture," Furber, *Trans. Illg. Eng. Soc.* 1910, p. 822.

"The Architect and Illuminating Engineering," Trimble, *Trans. Illg. Eng. Soc.*, 1912, p. 51.

[26] ART OF ILLUMINATION.

Decorative Aspects:

"Light and Color in Decoration," Hunter, *Trans. Illg. Eng. Soc.*, 1908, p. 190.

exteriors. The specialist applies daylight and artificial illuminants employing lighting auxiliaries and fixtures conforming to correct engineering, ocular and æsthetic principles in the lighting of interiors and exteriors. The art of illumination may be improved only as better materials of illumination are made available and as the science of illumination is advanced. In the lighting of interiors, more or less in accordance with established illuminating principles, much experience has been gained and recorded in recent years and considerable advance in practice has resulted. In the Transactions of the Illuminating Engineering Society alone there are more than 50 papers dealing with the illumination of interiors, many of them containing definite photometric data on the results obtained. This experience covers a wide variety of installations ranging from the illumination of churches and theatres through illumination of stores and factories to the simpler problems of lighting garages and stable.

That remarkable advances have been made in the *lighting of interiors* during the last five years will probably not be denied. Better materials of illumination are available and knowledge of correct principles of illumination has increased rapidly. Experiments in the design of lighting equipment and its installation have

"The Relationship of Decoration to the Illuminating Engineering Practice," Clifford, *Trans. Illg. Eng. Soc.*, 1910, p. 179.

Church Lighting:

"Church Lighting," Perrot, *Trans. Illg. Eng. Soc.*, 1908, p. 369.

"Indirect Lighting in Auditoriums," Wheeler, *Trans. Illg. Eng. Soc.*, 1912, p. 163.

"Church Lighting," Ely, *Trans. Illg. Eng. Soc.*, 1912, p. 613.

Lighting of Auditoriums and Theatres:

"The Illumination of Hammerstein's Philadelphia Opera House," Spillman, *Trans. Illg. Eng. Soc.*, 1909, p. 385.

"Theatre Illumination," Vaughn and Cook, *Trans. Illg. Eng. Soc.*, 1911, p. 961.

Office Lighting:

"The Illumination of the Building of the Edison Electric Illuminating Company of Boston," Bell, Marks and Ryan, *Trans. Illg. Eng. Soc.*, 1907, p. 603.

"Illumination of the Engineering Societies' Building, New York," Knox, *Trans. Illg. Eng. Soc.*, 1907, p. 445.

"Illumination of the Office Building of the Philadelphia Electric Company," Bartlett, *Trans. Illg. Eng. Soc.*, 1908, p. 555.

"Indirect Illumination of the General Offices of a Large Company," Aldrich and Mailia, *Trans. Illg. Eng. Soc.*, 1914, p. 103.

sometimes failed to give satisfaction, but usually have given some lesson which has added to the total experience in lighting practice. Developments which in themselves have not achieved permanent success have in some cases been stimulative, and have promoted the best development of lighting practice.

In the *lighting of exteriors* there has been some advance also. Street lighting is so largely dependent upon municipal appropriations that its development is sometimes hampered unduly by lack of funds. Merchants' associations have found in street lighting a means of promoting trade, and have had recourse to display street lighting to supplement the lighting provided by the city. Thus, tungsten cluster lighting has been installed in many cities, particularly the smaller cities of the country, with a very beneficial effect upon street lighting as a whole. More recently a competitive form of illumination, known as the "Ornamental Arc Lamp System," in which an inverted arc lamp is employed, has commanded much attention and is experiencing notable growth. General civic street lighting is improving slowly, the average standard of intensities being increased, and somewhat better de-

"Some Engineering Features of Office Building Lighting," Edwards and Harris, *Trans. Illg. Eng. Soc.*, 1914, p. 164.

School Lighting:

"Schoolhouse Illumination," Hatch, *Trans. Illg. Eng. Soc.*, 1907, p. 359.

"Public Schoolroom Lighting," Knight and Marshall, *Trans. Illg. Eng. Soc.*, 1910, p. 553.

Library Lighting:

"Design of the Illumination of the New York City Carnegie Libraries," Marks, *Trans. Illg. Eng. Soc.*, 1908, p. 538.

Store Lighting:

"The Lighting of a Large Store," Law and Marshall, *Trans. Illg. Eng. Soc.*, 1911, p. 186.

"Department Store Lighting," Shalling, *Trans. Illg. Eng. Soc.*, 1913, p. 17.

"Distinctive Store Lighting," Law and Powell, *Trans. Illg. Eng. Soc.*, 1913, p. 515.

"Present Practice in Small Store Lighting," Law and Powell, *Trans. Illg. Eng. Soc.*, 1912, p. 435.

Factory Lighting:

"Factory Lighting," Marks, *Trans. Illg. Eng. Soc.*, 1909, p. 805.

"Mill Lighting," Stickney, *Trans. Illg. Eng. Soc.*, 1911, p. 478.

"Factory Lighting," Flexner and Dicker, *Trans. Illg. Eng. Soc.*, 1913, p. 470.

sign of the illuminants and systems being noted in the more recent installations.

There is some little development in the way of lighting exteriors of buildings. Outline lighting of expositions was first carried out in a notable manner at the Columbian Exposition in 1893, attaining perhaps its highest development at the Pan-American Exposition in Buffalo in 1901. The Jamestown Exposition struck a new note in lighting building exteriors, and in the Panama-Pacific International Exposition in San Francisco, 1915, we are promised a fuller development of the lighting of buildings by concealed sources.

These occasional remarkable installations are, of course, few in number. There is no general tendency to light the exteriors of buildings, though a few creditable attempts have been made in this direction.

PROGRESS IN ILLUMINATION.

Having reviewed briefly the recent developments in the field of illumination, allow me to direct your attention briefly to the subject of progress and to the forces which have been responsible for improvements in the past and to which we must look for further development.

The illumination which is provided depends not only upon the

Show Window Lighting:

"Show Window Lighting," Henninger, *Trans. Illg. Eng. Soc.*, 1912, p. 178.

"Show Window Lighting," Wheeler, *Trans. Illg. Eng. Soc.*, 1913, p. 555.

Residence Lighting:

"Residence Lighting," Cravath, *Trans. Illg. Eng. Soc.*, 1906, p. 164.

"Some Home Experiments in Illumination from Large Area Light Sources," Ives, *Trans. Illg. Eng. Soc.*, 1913, p. 229.

"The Lighting of a Simple Home," Powell, *Trans. Illg. Eng. Soc.*, 1914, p. 45.

Passenger Car Lighting:

"The Lighting of Railway Cars," Hulse, *Trans. Illg. Eng. Soc.*, 1910, p. 75.

"Illumination of Passengers Cars," Minick, *Trans. Illg. Eng. Soc.*, 1913, p. 214.

"Modern Practice in Street Railway Illumination," Hibben, *Trans. Illg. Eng. Soc.*, 1913, p. 589.

"The Illumination of Street Railway Cars," Porter and Staley, *Trans. Illg. Eng. Soc.*, 1914, p. 25.

status of the art but also upon the degree to which practice conforms with the art. It has been stated that the art of illumination is improved as the materials of illumination are bettered and as the science of illumination is advanced. It may now be added that illuminating practice is improved as individuals, manufacturers in the lighting field, contractors in the lighting field, and lighting companies better their practice. It is to be regretted that in a review of recent progress in the field of illumination, note must be taken of the fact that illuminating practice has not advanced as rapidly as the development of the materials of illumination and the advance of the science of illumination would appear to make possible. The art of illumination has made rapid strides. Manufacturers, contractors, and lighting companies have improved their practice in many instances. Unfortunately, however, their influence is largely confined to new installations in stores and to some large manufacturing establishments. Where the commercial incentive is clearly discernible, old installations have been brought up to date very generally. With these exceptions the older installations, dating back ten years or more, compare unfavorably with the best that the art affords.

General:

"Indirect Illumination," Curtis and Morgan, *Trans. Illg. Eng. Soc.*, 1908, p. 740.

"Daylight Illumination," Marsh, *Trans. Illg. Eng. Soc.*, 1908, p. 224.

"Symposium on Indirect, Semi-Indirect and Direct Lighting," Rolph, Henninger and Hibben, *Trans. Illg. Eng. Soc.*, 1912, p. 234.

Street Lighting:

"A Method of Street Lighting by Incandescent Lamps," Underwood and Lansingh, *Trans. Illg. Eng. Soc.*, 1906, p. 115.

"Lighting of Streets by the Incandescent Mantle Burner System," Westermaier, *Trans. Illg. Eng. Soc.*, 1906, p. 122.

"Street Lighting," Bell, *Trans. Illg. Eng. Soc.*, 1908, p. 400.

"Street Lighting by Tungsten Lamps," Rhodes, *Trans. Illg. Eng. Soc.*, 1909, p. 54.

"Some Neglected Considerations Pertaining to Street Illumination," Millar, *Trans. Illg. Eng. Soc.*, 1910, p. 653.

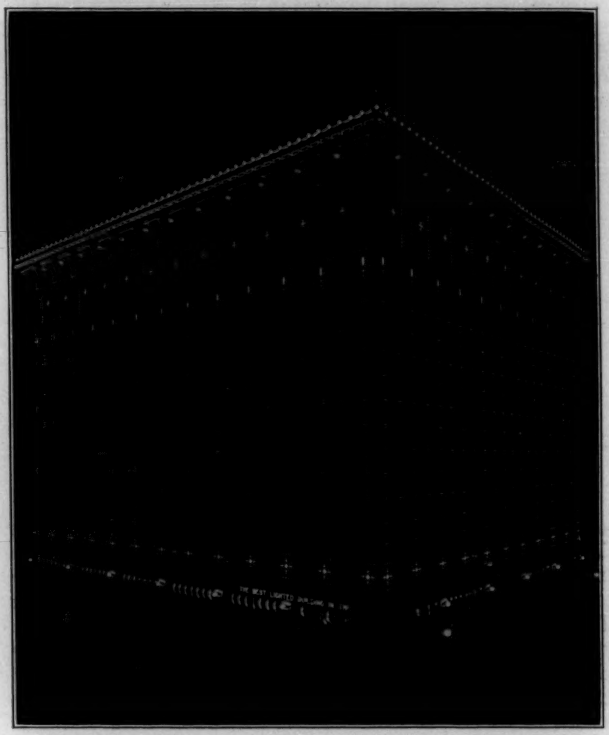
"Street Lighting with Ornamental Luminous Arc Lamps," Halvorson, *Trans. Illg. Eng. Soc.*, 1913, p. 88.

Lighting of Building Exteriors:

"The Lighting of the Buffalo General Electric Company's Building," Ryan, *Trans. Illg. Eng. Soc.*, 1912, p. 597.

Broadly speaking, a review of recent developments throughout the entire field must prove encouraging to all who are interested in the subject of illumination, with the single exception that means

FIG. 12.



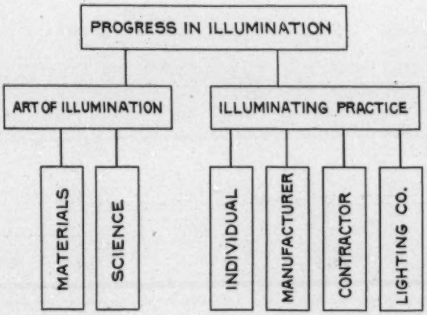
Building of the Denver Gas and Electric Company as lighted at night.

have not yet been devised for bringing old installations up to date and into conformity with present day knowledge of lighting principles.

FORCES TENDING FOR BETTERMENT IN THE ILLUMINATION FIELD.

The progress of the past few years in the field of illumination is largely traceable to definite sources, and consideration of these sources warrants the belief that recent progress may be taken as an earnest of further progress to be anticipated for the near future. The Illuminating Engineering Society is a forum for the discussion of lighting questions. It fosters study in the field, collects in its transactions most of the important literature of the art, and seeks to disseminate information regarding illumination. The Johns Hopkins University Illuminating Engineering Society

FIG. 13.



lecture course on illuminating engineering laid the groundwork for educational courses devoted to the subject, and a Committee on Education of the Illuminating Engineering Society is now seeking to further pedagogic interest and activity along this line. The national associations of electric companies and of gas companies are doing educational work in this field. The Illuminating Engineering Society is conducting a campaign of popular education. All of these efforts have made for progress, and may be looked to for future progress. The manufacturers of illuminants and accessories in this country are remarkably progressive. Their researches and investigations and educational work are bringing large results throughout the entire field. Lighting companies are awakening to the importance of illumination. While perhaps the power business in both the electric and gas industries

is assuming greater importance than the lighting business, yet it is the lighting business upon which the reputation of the company for furnishing good service or poor service is most likely to depend, and which offers far more opportunity for cultivating public good-will through acceptable service than does the power business. Most large electric and gas companies now have on their staff one or more illuminating engineers, and are devoting more attention than formerly to the subject of good illumination.

FIG. 14.

ADVANCES IN SCIENCE OF ILLUMINATION DURING RECENT YEARS

CONCEALMENT OF BRILLIANT LIGHT SOURCES.
KNOWLEDGE OF QUALITIES OF ILLUMINANTS AND AUXILIARIES.
CONCEPT OF LIGHT FLUX.
COLLECTION OF PHOTOMETRIC ILLUMINATION DATA.
AVOIDANCE OF EXTREMES IN CONTRAST.
APPRECIATION OF ARTISTIC REQUIREMENTS.
FIRST GLIMMERINGS OF RECOGNITION OF PSYCHOLOGICAL REQUIREMENTS. (1914.)

IMPORTANCE OF THE SUBJECT.

In conclusion, allow me to enter a plea for more general attention to the subject of illumination. It is one of transcending importance whether viewed from a humanitarian or a commercial standpoint. Some estimates for the year 1913 of its commercial importance in this country have recently been published.[27] According to these the manufacturer's sales of materials employed directly for illumination in the electric lighting industry alone aggregated $65,000,000, while the sales of machinery involved in the generation of electricity for lighting purposes aggregated perhaps half of this amount. The revenue of central stations derived from the electric lighting business is estimated as exceeding $300,000,000. These figures suggest in some measure the importance of the electric lighting industry and of course are in need of supplement by corresponding figures representative of the gas lighting industry and of the miscellaneous lighting business of the country. But if all such figures were available, they would only begin to suggest the commercial importance of arti-

[27] Editorial, *Lighting Journal*, January, 1914.

ficial illumination to the country. Who shall attempt to estimate the colossal additions to the wealth of the nation which it makes possible through extending the hours of industry?

The importance of artificial illumination in another sense is difficult to overestimate.

"*Health* in the home is dependent upon proper sanitation. 'Cleanliness is next to Godliness'; without proper light, cleanliness is next to impossible! Adequate illumination promotes cleanliness.

"Ophthalmologists tell us that inadequate or otherwise improper illumination occasions eye-strain which often results in headache and other nervous disorders. These, if prolonged, sooner or later undermine general health. So, good illumination affects general health by promoting sanitation and avoiding nervous strain.

"Good illumination has a more direct bearing upon the health of the eyes. If the eyes are closely employed upon detailed work, as in sewing or reading, under conditions of illumination which are improper, the eyes are fatigued, and if the occupation is continued, in spite of the fatigue, vision is impaired at least temporarily, and possibly is injured permanently. As compared with our forefathers we are distinctly a nocturnal people. We use our eyes a greater number of hours per day. Oculists' records testify, and the prevalence of eye-glasses evidences, the deleterious effects upon the vision of the people as a whole. Who shall say what part of the prevalence of impaired vision is attributable to improper illumination, that is to say, to the misuse of light?

"Physiologists tell us that the human eye is naturally adapted for distant vision; that when focused upon nearby objects, as in most of the work in which it is applied in our modern life, the muscles are contracted and the focal mechanism of the eye is subjected to strain. They tell us also that, just as children are physically, intellectually, and morally more susceptible and pliant than adults, so the visual organs of children are delicate and especially liable to injury if used under adverse conditions. In modern life children are called upon for a large amount of home-work in connection with the school systems. This involves application of the eyes in exacting near vision to which they are not naturally adapted, and at a time of life in which they are peculiarly liable to injury. When to these untoward conditions there is added that

of poor illumination, is it any wonder that we are becoming a bespectacled race? Of these conditions which operate against ocular welfare some may be beyond our control, but that of poor illumination is a menace for the existence of which there is no excuse, since the remedy is understood and is available to all.

"Light has a marked bearing upon the *usefulness* of our lives. Artificial light extends the hours in which we may labor. It makes possible intellectual improvement; it permits added achievement; it makes actual life of fifty years equivalent to a much longer life in the period antedating the perfection of our modern light sources. Yet, though these statements are in general correct, it remains true that the precise measure of added usefulness which artificial light makes possible depends upon the merits of the illumination. With good illumination one may labor to better effect, may produce more largely, and the product will be more nearly perfect than with poor illumination. These facts may be applied to the industries and to the arts, to manufacture, to the pursuit of knowledge, or to the development of artistic talent.

"Artificial light is an important factor in promoting *happiness*. In extending the hours of activity beyond those which are ordinarily devoted to the duties of life, it affords opportunity for the pursuit of pleasure. Light reveals the beauties of nature and of art, whether it be sculpture, painting, or architecture. It is particularly important in the home where so much effort is expended for the comfort and pleasure of the family. Few homes are so humble but that some effort is made to render them attractive. The home usually reflects in its decorations the personality of the home-maker, and, within the limits of the tastes and means of the family, attempt is generally made to render it homelike and charming. Much of the beauty and charm are lost in the evening if the rooms are not properly illuminated." [28]

Considering the immense importance of artificial illumination as a factor in the progress of the country, every advance in the science of illumination, every improvement in the materials of illumination, and all progress in the art has a special significance—even a minor improvement in materials or in the science may have a large general influence if embodied in standard practice. It is

[28] Mrs. P. S. Millar, Froebel Society, Brooklyn, November, 1913.

therefore of interest to consider the improvements which have been brought about in the recent past, the discrepancy between some of the present practice and the best that the art affords, and the opportunity which each one of us has to influence one or more lighting installations for good. Considering the importance of the subject and the progress being made, it is a gratifying task to undertake to report upon recent developments, even though such report is recognized as being but little more than suggestive as to the facts.

Influence of the Casting Process on Wrought Non-ferrous Materials. ANON. (*Amer. Mach.*, xli, No. 8, 329.)—In a discussion before the American Society for Testing Materials it was pointed out that the surface of molten brass becomes instantly covered with a thick film of oxide on exposure to the air, and this oxide must be prevented from becoming incorporated in the solidified metal. Two instances will illustrate the importance of proper casting. Ingot copper of the finest character, as received from the refining furnace, is neither very ductile nor malleable when cold, but when properly melted and cast from a crucible it becomes highly so. A properly cast billet should show no pipe at the upper end, but when improperly cast a considerable pipe may occur. The casting process, when properly performed, leaves the bar, billet, or ingot free from blow-holes, gas cavities, or dirt, and from surface imperfections.

Luminosity of Neon Tubes as a Function of Their Diameter. G. CLAUDE. (*Comptes Rendus*, clviii, 692.)—The author has verified the law of variation of fall of potential as a function of the diameter of neon tubes along the luminous column of those tubes. The object of the present experiments is to ascertain the consequences of this law from the point of view of luminosity. The table of results shows that the lighting power, with equal current densities, does not increase in proportion to the sections, but barely as the diameters. Now, if the current increases as the square of the diameter, the fall of potential in the column decreases inversely as the diameter, so that taken altogether the electric power absorbed in the column increases only as the diameter, and, as the lighting power increases approximately according to the same law, it follows that the quantity of light produced is connected with the energy expended. When considering the output of the luminous column only, both very large and very small tubes are at a disadvantage. Quite satisfactory results, however, can be obtained with tubes of diameters 40 mm. to 10 mm. The lighting power furnished by a tube of given length diminishing very nearly as its diameter without the output suffering, it is therefore possible to arrange a very economic form of lighting.

THE QUALITY OF THE TWENTY-FOUR-INCH OBJECTIVE OF THE SPROUL TELESCOPE, AS DETERMINED BY HARTMANN TESTS.*

BY

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THE telescope for the Sproul Observatory was completed in the summer of 1911 and mounted in the observatory the following December. The objective of the telescope, which was built by the John A. Brashear Co., Ltd., is 24 inches in diameter, and has a focal length of approximately 433 inches. The lens was made from a Crown disc furnished by the Parra-Mantois firm, of Paris, and a flint disc furnished by Schott and Genossen, of Jena. In February of 1912, the writers began a test of the lens, using the method of extra-focal images devised by Hartmann,[1] and applied by him, and also by others, to numerous objectives, the most notable of which is perhaps the test of the 80 cm. objective of the Potsdam refractor. The method of making this test has been frequently described[2] and the reader will recall its essential features. The objective is covered with an opaque screen in which a suitable number of circular openings have been made, through which light from a star (or other source) can pass. These openings serve to isolate such parts of the lens as the observer chooses to test.

If the focus of the telescope is at F^1, and if the bundles of rays that come from a pair of holes intersect a plane P_1, within the focus, at the points B and C respectively, one can measure $BC = e_1$ (say). If also the bundles of rays that come from the

* Communicated by Professor Miller.

[1] Hartmann: *Zeitschrift für Instrumentenkunde*, vol. 24.
Plaskett: *Astrophysical Journal*, vol. 25.
Fox: *Astrophysical Journal*, vol. 27.

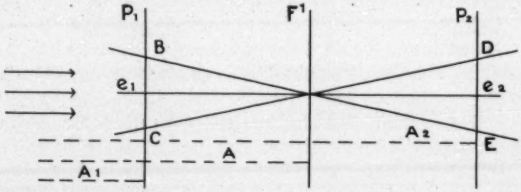
[2] Opera cited: Pub. des Astrophysikalischen Obs. zu Potsdam, Nr. 46.

same pair of holes intersect a plane P_2, without the focus at the points D and E, one can measure the distance $DE = e_2$ (say). If, further, he knows the distance between P_1 and P_2, he can by solving similar triangles calculate the distance of F, the intersection of the beams from any pair of openings, diametrically situated on the same zone, from the plane P_2 by the formula—

$$A_2 - A = \frac{e_2}{e_1 + e_2}(A_2 - A_1) \qquad (1)$$

where A_1, A_2 and A are respectively the distances of P_1 and P_2 and F from the optical centre of the objective. This formula, including the notation, is practically the same as the one which was deduced by Hartmann, which we modified slightly in order that we might compute $A_2 - A$, the distance of F from the plane P_2, instead of its distance from the objective as Hartmann did.

FIG. 1.



The distances e_1 and e_2 may be measured with a micrometer, or, having let the rays fall on a photographic plate, the distance between the images may be measured on the plate. The latter is the more convenient way. Now, the quantity $A - A_2$ will depend chiefly upon the objective, but it will be influenced by the color of light being used, and also upon the character of the plate. One might, as Hartmann did in many of his tests, render the rays of light monochromatic by using the spectroscope. This we did not do, our object being rather to determine the quality of the objective under the same circumstances that the telescope is being used. The telescope at present is used chiefly for making photographs for the determination of stellar parallax. The objective is corrected for visual rays, and in order to use the flattest part of the field we photograph through a ray filter, made for us by

Wallace, which is opaque to the violet end of the spectrum and nearly so for the red end. The filter is made of optical glass and is placed very close to the plate. We use Cramer's Instantaneous Isochromatic Plates. The photographs for making the extra-focal test of the objective, which is discussed in what follows, were made in this way.

EARLIER TESTS.

Our first attempt was made on February 22, 1912. Six exposures were made on Capella, when it was near the meridian, through a screen containing 44 circular holes, each 33 mm. in diameter, so arranged as to cover nine zones of the objective. Six sets of plates were made, measured, and reduced. Hartmann's characteristic quantity [3] T, which measures the quality of a lens, calculated from these plates was small ($=.27$). But the measures showed certain discrepancies among the focal distances of different parts and zones of the lens that, although not excessive, were absent when the objective was in the optical room.

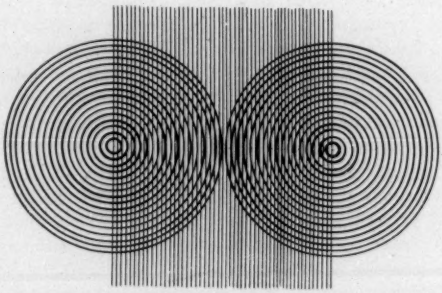
The objective is prevented from sliding in its cell by the pressure of a spring on one side of it, and Mr. McDowell, of the Brashear Company, suspected that these discrepancies might be due to this pressure. Later, June 5, 1912, we reduced this pressure and repeated the extra focal test, using Arcturus when it was near the meridian. The screen used in this test contained 78 circular openings each 25 mm. in diameter, so arranged that we could investigate ten zones. We found that, although the exposures on Capella were made when the temperature was low and with the telescope east of the pier, while those on Arcturus were made when the temperature was high and the telescope west of the pier, those parts of the objective that showed short (or long) focus in one of the tests showed the focus short (or long) in the other test also, though in the second case they were numerically smaller.

The extra-focal images, at least, are not good, and the smaller the openings the worse they are. But the larger the opening the smaller the number that can be put into the screen, and the less exhaustive the test is. Moreover, the plates must be put far enough out of focus so that images in the pattern, resulting from

[3] *Zeitschrift für Instrumentenkunde*, Bd. 24.

intercepting the beams from the separate holes, may not overlap each other. Having these natural precautions in mind, it so happened that when we made the first screen for photographing Capella we chose values for the radius of the circular opening and the distance of the plates from the focus in such a way that a most peculiar condition resulted. Between each two adjacent images on a diameter there was found a spurious image elongated in a direction perpendicular to the radius upon which the openings lay. We afterwards increased the radius of the openings and changed the extra-focal differences somewhat, thereby eliminating these spurious images entirely.

FIG. 2.



However, we were curious to know the relation that must exist between these various magnitudes in order that the spurious images might appear, or rather would not appear. Miss Marion R. Stearne, then a Senior in Swarthmore College, investigated the matter and found that these spurious images are interference effects and deduced a formula by which one might construct a screen, giving extra-focal patterns from which these spurious images are absent. Miss Stearne found that these spurious images were due to systems of circular maxima and minima (those resulting from the diffraction pattern of a single aperture) which are crossed by alternate dark and bright bands, which are arcs of hyperbolæ and which differ very little from straight lines which are perpendicular to the line joining the centres of the images of the star from two adjacent apertures as in the figure

—and are due to interference of the beams coming from the two apertures.

Below follows a *résumé* of Miss Stearne's work:

Let i = intensity of the illumination at any point of a plane by light coming through a single circular aperture.

Let I = intensity of illumination of any point of a plane by light coming through two circular apertures, of equal radii.

c = distance between the centres of the apertures.

ϕ = angle of diffraction.

λ = wave-length of light.

r = radius of the apertures.

It is proved in physical optics that if light comes through a single circular aperture, there results a system of concentric circular maxima and minima of intensity of illumination of a plane. The minima of intensity are all zero. The centres of these circular maxima and minima coincide with the centre of the images, and their angular radii, θ, as seen from the optical centre is (m an integer):

$$\theta = \frac{m\lambda}{r}$$

Let us call these the first system of maxima and minima. It is further proved in physical optics that

$$I = 4i \sin^2\left(\frac{\pi c}{\lambda} \sin\phi\right).$$

If we now fix our attention on a particular maximum of the first system, then i is constant.

If we put $\frac{dI}{d\phi} = 0$, one finds either

$$\cos\phi = 0$$

or

$$\sin\left(\frac{2\pi c}{\lambda} \sin\phi\right) = 0.$$

And since $\frac{\pi}{2}$ is not an admissible value,

$$\sin\phi = \frac{n\lambda}{2c}.$$

When n is odd, $\frac{d^2I}{d\phi^2}$ is negative, and hence for these values I is a maximum.

When n is even, $\frac{d^2I}{d\phi^2}$ is positive and hence for these values I is a minimum. That is, there results a system of alternately dark and bright bands, which are straight lines perpendicular

to the line joining the centres of the apertures. Accordingly, in addition to the precautions mentioned on page 467 it becomes necessary to eliminate these bands that arise from the interference of the beams that come from two adjacent apertures. Since ϕ is small we may put $\sin \phi = \phi = \frac{n\lambda}{2c}$; that is, the distances of these bands from a line perpendicular to one joining the centres of the images are inversely proportional to the distance between the centres of the apertures, while the radii of the first system of circular apertures vary inversely as the radius r of the apertures. We can therefore eliminate these to any degree of approximation either by properly choosing r and c, or by placing the plates far enough from the focus; the latter method has the objection that the far-out-of-focus images are not measurable.

Let θ = the angular radius of the nth maximum of the circular system, and if we put,

$$m_n = \frac{\pi r \sin \theta}{\lambda} = \frac{\pi r \theta}{\lambda}$$

$$\theta = \frac{m_n \lambda}{\pi r}.$$

It can be shown from the geometric properties of image formation that the interference from the beams through two adjacent apertures can be eliminated to the $\left(\frac{n}{2}\right)$ th band, if we put

$$\frac{m_n \lambda}{\pi r} > \frac{2n\lambda}{2c}.$$

Also if—

f = focal length of the objective,

x = distance of the plate from the focal plane,

h = distance from the axis of the objective to the extra-focal image.

Then,

$$\frac{f-x}{h} < \frac{2c}{n\lambda} = \frac{r}{\lambda};$$

$$\frac{x}{h} = \frac{2f}{c}$$

$$\frac{f}{h} < \frac{r}{\lambda} + \frac{2f}{c}$$

$$x = \frac{2fh}{c}$$

That is, if one is testing an objective of focal length, f, having chosen two of the quantities r, n, c or x, arbitrarily, he may determine the remaining ones from the preceding equations and inequalities, so that the spurious images mentioned above are absent.

THE FINAL TEST.

In 1913, we decided to repeat the Hartmann test of the objective, after having again reduced the pressure of the spring referred to on page 467. We constructed screens meeting approximately the foregoing specifications, choosing $n = 9$, and $r =$ 18 mm.; hence since for our objective $f = 11{,}010$ mm. approximately, $c = 81$ mm., and $x = 90$ mm. approximately.

Because the photographic eyepiece of the telescope made it convenient to do so, instead of $x = 90$ mm., we chose to separate the planes P_1 and P_2 by 200.5 mm. The resulting images were the best we had obtained.

In order to cover the lens very completely, we decided to use three screens.

Screen No. 1. Contained 32 holes, arranged on 8 zones; the radii of the zones on this screen were 2, 5, 6.5, 8, 8.75, 9.5, 10.25, and 11 inches.

Screen No. 2. Contained 36 holes, arranged on 9 zones; the radii of these zones were 2.25, 4.25, 5.25, 7.25, 8.375, 9.175, 9.875, 10.625, and 11.375 inches.

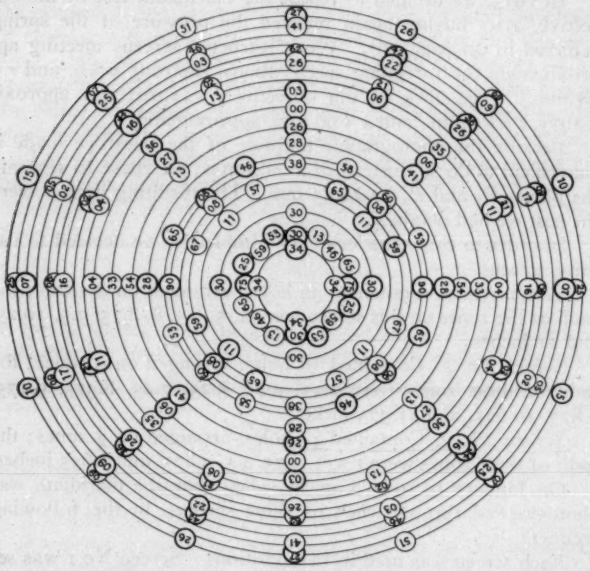
Screen No. 3. Contained 14 holes, arranged on 7 zones; the radii of these zones were 1.5, 3, 3.75, 4.5, 5.875, and 7.625 inches.

On January 9, 1913, Capella, when near the meridian, was photographed through each of these screens, in the following manner:

Each screen was used in two positions. Screen No. 1 was set with a given diameter parallel to the equator, and five exposures made. It was then rotated through 45 degrees about an axis through the centre of the lens perpendicular to the plane of the screen and five additional exposures made on another plate. Screen No. 1 was then removed and Screen No. 2 placed over the lens, and, five exposures through it having been made, it was turned 45 degrees and five additional exposures made on another plate. Screen No. 2 was then removed and Screen No. 3 put in its place, and, five exposures having been made, it was

turned through 90 degrees. Integrating these results, this was equivalent to photographing through a single screen containing 164 holes, arranged on 24 zones. There were 8 holes on each of 17 zones and 4 holes on each of 7 zones. These holes were distributed on diameters making angles of 22½ degrees with each other. Fig. 3 shows this integrated screen.

FIG. 3.



It will be noted (see Fig. 3) that some of the holes partially overlap each other. The numbers in the holes show the number of *hundredths of a millimetre* that that particular part of the lens was in error. The heavy circles represent the positions in which the lens focused too short, and the light circles where it focused too long. The arrangement of the holes is also exhibited in Table I.

We used every precaution possible to eliminate local errors. The screens had been in the dome room for several hours pre-

vious to making the photographs in order that they might be of the same temperature as the lens. The screens were constructed carefully and oriented so that the centre of the screen was superimposed on the centre of the objective. Each set of five exposures was made on the same plate. The first exposure was in the centre of the plate and the remaining four grouped symmetrically around the centre one, displaced just enough so that their patterns did not overlap each other. The plates were then measured on a measuring engine, one set each by Prof. S. G. Barton and the writers. The results are exhibited in Table I. It will be noted that Dr. Barton measured only those plates which were made before the screens were turned, through 45 and 90 degrees respectively. The agreement between his measures and those of the writers' are satisfactorily accordant.

If one, by means of formula (1), compute A, the distance from a fixed plane, of the juncture of the rays coming from two holes, he will find, except in the case of a perfect objective, that

$$A = f(\phi, r, \lambda).$$

If when r and λ are constant, A shows a dependence on ϕ, the lens is astigmatic. If the astigmatism is regular and small we may assume, as Hartmann does, that there is one meridional section, making an angle of ϕ_0 with some arbitrarily chosen zero meridional section for which A is a minimum, and another making an angle of $\phi_0 + 90°$ for which A is a maximum; and further that, following Hartmann's notation, if ${}_\phi A$ denote the value of A in a meridional section making an angle ϕ with the zero section, then ${}_\phi A$ may be computed by the formula,

$${}_\phi A = {}_{\phi_0} A + a \sin^2 (\phi - \phi_0) \qquad (2)$$

where a is the numerical difference between the greatest and least value of A for any given zone. Hence,

$$\frac{1}{2}({}_\phi A + {}_{\phi+90^\circ} A) = {}_{\phi_0} A + \frac{a}{2}$$

If one computes ${}_\phi A$ for all meridional sections of any zone of radius r, for which he has observational data (in our case this number varies from 2 to 4), and if he let A^r be the mean of all the values of ${}_\phi A$ thus obtained for any one zone, it is evident that

$$A^r = {}_\phi A + \frac{a}{2}$$

Put now,

$$R = {}_\phi A - A^r$$

then,

$$R = -\frac{a}{2}\cos 2(\phi - \phi_0) \qquad (3)$$

Thus, every two meridional sections give two equations for the determination of a and ϕ_0. Where there are more than two meridional sections, as is true for most of the zones that we measured, normal equations may be formed and solved. This is the method described by Hartmann and applied by him to the 80 cm. refractor of the Potsdam Observatory. In making the test of the Potsdam refractor, Hartmann constructed the screen so that two zones had openings on more than two diameters and solving the normal equations, formed from the measures of these zones, he found that they gave fairly accordant results for those two zones; that is, the value of a, and ϕ_0 obtained from the solutions for the two zones did not differ widely. We had openings on more than two diameters in 17 zones. We formed the normal equations for each of these zones, and solved them for the quantities a and ϕ_0. The value of ϕ_0 for all these zones showed little if any tendency to collect around any meridional section. The results of the computation are found in column 15 of Table I.

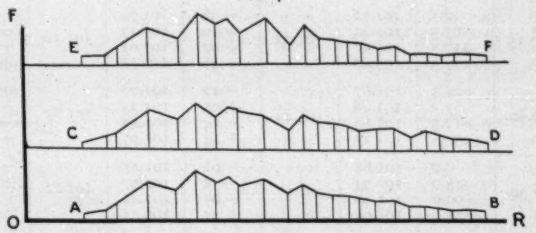
Having obtained a and ϕ_0 for any one zone, we computed R' by substituting in equation (3) the value of ϕ_0 and a found by computation. These quantities R are the computed astigmatisms. The results thus obtained show clearly that there is no regular astigmatism in the lens.

Table I is a summary of the arrangement of the openings in the screen, and the results of the measures. For the sake of ready reference, we give here a description of the table. All linear magnitudes are given in millimetres. Column 1 contains the radii of the zones, column 2 the angles that the meridional section made with a meridional section parallel to the equator, measured in a counter clock-wise direction as seen from the eye end of the telescope. Columns 3, 4, and 5 contain the quantities ${}_{\phi}A^{r}$, A^{r}, and R as determined by Marriott, where ${}_{\phi}A^{r}$ is the distance of the focus from the plane P_2 (Fig. 1), *i.e.* from the plane of the photographic plate which was exposed farthest from the objective, as determined by the juncture of the rays from two openings, in a zone of radius r, and in a plane making an angle ϕ with a plane parallel to the equator, A^{r} the means of the ${}_{\phi}A^{r}$ in any zone and R are the astigmatisms. Columns 6, 7, and 8 contain

the same quantities as determined by Miller, columns 9, 10 and 11 the values as determined by Barton, column 12 contains A^r_m the means of A^r, as determined by Marriott and Miller, column 13 the mean of the R's as determined by the same observers, columns 14 and 15 the value of a and ϕ_0 as computed by equation (3), column 16 the computed astigmatisms, column 17 the value $\Delta = R - R'$. Even a casual glance at Table I will show that in the region of the zone $r = 5$ inches, the lens focuses shorter than at any other place.

The curves in Fig. 4 are the curves of zonal error; the abscissa of any point is the radius of zone, and the corresponding

FIG. 4.



ordinate is the quantity A_r diminished by a constant and multiplied by .25. So that the difference of any two ordinates is 25 times the difference in the focal length of two zones; that is, the errors are magnified 25 times. The actual difference between the greatest and least focal length of any two zones is less than 1.1 mm. The curves *EF*, *CD*, and *AB* are respectively the graphs of the measures made by Miller and Marriott, and the mean of those measures.

We computed the diameters, d_i, of the circles of confusion for each of the 24 zones in that plane, whose distance from the plane P_2 is A_o where A_o is determined by Hartmann's formula:

$$A_o = \frac{r_h A_h + r_k A_k}{r_h + r_k},$$

where h and k are determined by the condition that no diameter of confusion shall be greater than d where

$$d = 2r \frac{(A_3 - A_o)}{F},$$

TABLE

r	Φ	ϕA_r	A^r	R_1	ϕA^r	A^r	R_2
288.92	22.5°	101.62	101.13	−.49	101.70	101.18	−.52
	67.5	101.00		+.12	101.00		+.18
	112.5	101.03		+.10	101.07		+.11
	157.5	100.85		+.27	100.94		+.24
279.40	0.0	100.99	101.25	+.26	100.90	101.20	+.29
	45.0	101.14		+.10	101.15		+.04
	90.0	101.52		−.27	101.43		−.24
	135.0	101.34		−.09	101.29		−.09
269.87	0.0	101.59	101.23	−.36	101.63	101.18	−.45
	45.0	101.10		+.13	100.80		+.38
	90.0	101.07		+.15	101.20		−.02
	135.0	101.14		+.09	101.09		+.09
260.35	22.5	101.72	101.34	−.38	101.70	101.16	−.54
	67.5	101.44		−.10	101.15		+.01
	112.5	101.32		+.02	101.01		+.15
	157.5	100.87		+.46	100.78		+.38
250.82	22.5	101.67	101.49	−.12	101.22	101.27	+.06
	67.5	101.48		+.01	101.33		−.06
	112.5	101.63		−.14	101.48		−.21
	157.5	101.25		+.24	101.07		+.21
241.30	0.0	101.88	101.27	−.61	101.85	101.22	−.63
	45.0	100.93		+.34	100.87		+.31
	90.0	101.20		+.07	101.44		−.22
	135.0	101.05		+.21	100.71		+.51
233.04	0.0	101.90	101.56	−.34	101.60	101.43	−.18
	45.0	101.32		+.23	101.34		+.09
	90.0	101.76		−.20	101.54		−.12
	135.0	101.24		+.32	101.22		+.21
222.25	22.5	101.50	101.51	+.01	101.42	101.37	−.05
	67.5	101.48		+.03	101.36		+.01
	112.5	101.30		+.21	101.15		+.22
	157.5	101.75		−.24	101.56		−.19
212.75	22.5	101.65	101.48	−.17	101.57	101.48	−.09
	67.5	101.53		−.06	101.51		−.03
	112.5	101.31		+.16	101.43		+.06
	157.5	101.41		+.07	101.43		+.06
203.20	0.0	101.56	101.54	−.02	101.43	101.52	+.09
	45.0	101.14		+.39	101.19		+.32
	90.0	101.55		−.01	101.58		−.07
	135.0	101.90		−.36	101.86		−.35
193.67	45.0	101.52	101.64	+.11	101.49	101.57	+.08
	135.0	101.75		−.11	101.65		−.08
184.15	0.0	101.68	101.67	−.01	101.66	101.67	+.01
	45.0	101.41		+.26	101.37		+.29
	90.0	102.08		−.40	101.92		−.26
	135.0	101.52		+.15	101.71		−.05
174.62	0.0	102.07	101.86	−.21	102.34	101.99	−.35
	90.0	101.65		+.21	101.65		+.35

I.

ϕA^r	A^r	R_3	A''_n	R	a	Φ_0	R'	Δ
				−.51			−.30	−.21
101.01		−.13	101.15	+.15	.62	27°36′	−.05	+.20
	100.88			+.10			+.30	−.20
100.74		+.13		+.26			+.05	+.21
100.92		+.38		+.27			+.26	+.01
	101.30		101.22	+.07	.54	98°45′	+.08	−.01
101.69		−.38		−.25			−.26	+.01
				−.09			−.08	−.01
				−.41			−.24	−.17
101.03		−.13	101.20	+.25	.50	170°45′	+.08	+.17
	100.90			+.07			+.24	−.17
100.76		+.13		+.09			−.08	+.17
				−.46			−.27	−.19
101.14		−.14	101.25	−.05	72	42°45′	−.23	+.18
	101.00			+.09			+.27	−.18
100.85		+.14		+.42			+.23	+.19
101.24		+.09		−.03			+.07	−.10
	101.33		101.38	−.02	.28	82°37′	−.12	+.10
101.42		−.09		−.17			−.07	−.10
				+.22			+.12	+.10
				−.62			−.26	−.36
100.78		+.07	101.24	+.34	.55	1°03′	−.01	+.35
	100.85			−.08			+.26	−.34
101.91		−.07		+.36			+.01	+.35
101.11		+.27		−.26			−.05	−.21
	101.38		101.49	+.16	.14	22°30′	−.05	+.21
101.64		−.27		−.16			+.05	−.21
				+.26			+.05	+.21
101.05		−.15		−.02			−.11	+.09
	100.90		101.44	+.02	32	180°00′	+.11	−.09
100.76		+.15		+.21			+.11	+.10
				−.21			−.11	−.10
				−.13			−.12	−.01
101.48		−.06		−.04			−.05	+.01
	101.42		101.48	+.11	.26	33°48′	+.12	−.01
101.37		+.06		+.06			+.05	+.01
101.43		+.06		+.03			+.00	+.03
	101.49		101.53	+.36	.71	134°36′	+.35	+.01
101.56		−.06		−.04			−.00	−.04
				−.35			−.35	−.00
102.02		−.25		+.09			+.09	−.00
101.53	101.77	+.25	101.60	−.09	.18	135°00′	−.09	−.00
				−.00			+.17	−.17
101.54		−.04		+.27			+.11	+.16
	101.50		101.67	−.33	.39	106°14′	−.17	−.16
101.47		+.04		+.06			−.11	+.17
102.20		−.30		−.27			−.27	−.00
101.61	101.90	+.30	101.93	+.27	.54	0°00′	+.27	+.00

TABLE

r	Φ	ϕA^r	A^r	R_1	ϕA	A^r	R_2
165.10	0.0°	101.15	101.47	+.32	101.25	101.46	+.21
	45.0	101.62		−.15	101.57		−.12
	90.0	102.05		−.57	101.97		−.52
	135.0	101.07		+.40	101.03		+.43
149.22	0.0	101.97	101.86	−.11	102.60	102.14	−.46
	90.0	101.75		+.11	101.68		+.46
133.35	22.5	101.54	101.99	+.45	101.28	101.75	+.47
	67.5	101.38		+.61	101.06		+.69
	112.5	102.50		−.50	102.30		−.55
	157.5	102.55		−.55	102.35		−.60
127.00	0.0	102.45	102.05	−.40	102.47	102.09	−.38
	45.0	102.05		+.00	101.94		+.16
	90.0	101.20		+.85	101.13		+.96
	135.0	102.51		−.46	102.84		−.75
116.84	45.0	101.87	101.77	−.10	102.07	102.02	−.06
	135.0	101.66		+.10	101.96		+.06
107.95	22.5	102.71	102.12	−.59	102.86	102.30	−.56
	67.5	102.80		−.68	102.97		−.67
	112.5	101.47		+.65	101.76		+.54
	157.5	101.50		+.62	101.62		+.68
95.25	45.0	101.91	101.72	−.19	101.69	101.66	−.04
	135.0	101.52		+.19	101.62		+.04
76.20	0.0	102.34	101.98	−.36	102.17	101.93	−.24
	90.0	101.62		+.36	101.69		+.24
57.15	22.5	100.84	101.30	+.46	100.84	101.45	+.61
	67.5	100.98		+.32	101.27		+.18
	112.5	102.07		−.77	101.99		−.54
	157.5	101.31		−.01	101.71		−.26
50.80	0.0	100.94	101.27	+.33	101.92	101.19	+.27
	45.0	101.86		−.58	101.78		−.59
	90.0	100.61		+.66	100.35		+.84
	135.0	101.68		−.41	101.69		−.50
38.10	0.0	100.68	101.04	+.35	100.84	101.18	+.34
	90.0	101.38		−.35	101.52		−.34

(All linear magnitudes in this

I.—*Continued*

ϕA^r	A^r	R_3	A_n^r	R	a	Φ_0	R'	Δ
				+.26			+.39	−.13
100.75		+.20		−.13			−.26	+.13
	100.95		101.46	−.54	.96	72°59′	−.39	−.15
100.16		−.20		+.41			+.26	+.15
102.08		−.22		−.28			−.28	−.00
101.64	101.86	+.22	102.00	+.28	.56	0°00′	+.28	+.00
				+.46			+.48	−.02
101.40		+.15		+.65			+.60	+.05
	101.55		101.87	−.53	1.57	138°05′	−.48	−.05
101.71		−.15		−.58			−.60	+.02
102.43		−.80		−.38			−.64	+.26
	101.63		102.07	+.08	1.45	165°50′	+.34	−.26
100.83		+.80		+.90			+.64	+.26
				−.60			−.34	−.26
102.67		−.12		−.08			−.08	−.00
102.44	102.55	+.12	101.89	+.08	.16	45°00′	+.08	+.00
101.62		−.12		−.57			−.54	−.03
	101.40		102.21	−.67	1.75	46°50′	−.61	−.06
101.19		+.12		+.59			+.54	+.05
				−.65			+.61	+.04
102.43		−.35		−.11			−.11	−.00
101.72	102.08	+.35	101.68	+.11	.22	45°00′	+.11	+.00
102.43		−.58		−.30			−.30	−.00
101.27	101.85	+.58	101.95	+.30	.60	0°00′	+.30	+.00
				+.53			+.59	−.06
101.50		−.47		+.25			+.19	+.06
	101.03		101.37	−.65	1.24	127°25′	−.59	−.06
100.56		+.47		−.13			−.19	+.06
99.94		−.04		+.30			−.22	+.52
	99.90		101.23	−.59	.46	8°00′	−.06	− 53
99.87		+.04		+.75			+.22	+.53
				−.46			+.06	−.52
101.49	100.77	−.72	101.11	+.34	.68	0°00′	+.34	+.00
100.06		+.72		−.34			−.34	−.00

table are given in millimetres.)

where s takes the values h and k, and F is determined by the Gauss-Hartmann method and is found to be 11,010.9 mm. (433.5 inches).

TABLE II.

1	2	3	4	1	2	3	4
r	d	d	d	r	d	d	d
288.92	.133	.158	.143	174.62	.129	.139	.138
279.40	.073	.146	.106	165.10	.016	.015	.002
269.87	.080	.147	.111	149.22	.110	.055	.135
260.35	.030	.150	.085	133.35	.127	.052	.092
250.82	.033	.097	.028	127.00	.132	.122	.130
241.30	.055	.116	.083	116.84	.069	.097	.084
233.04	.057	.032	.015	107.95	.130	.141	.135
222.25	.036	.050	.003	95.25	.048	.022	.037
212.75	.024	.008	.010	76.20	.071	.052	.064
203.20	.043	.001	.026	57.15	.010	.053	.066
193.67	.071	.019	.047	50.80	.011	.026	.010
184.15	.076	.046	.066	38.10	.075	.020	.021

Table II gives the diameters of the circles of confusion for each of the 24 zones in the plane at a distance A_0 from P_2. These diameters are expressed in *hundred-thousandths of the focal length*. The maxima of these diameters of confusion as determined by Marriott and Miller are respectively .133 and .158, while the maximum of the diameters as determined by using the mean of the measures of Marriott and Miller is .143. This we have called the "Resultant" of the two sets of measures. These quantities might be taken as the characteristic quantity that determines the quality of the objective since Hartmann's quantity "T" is the weighted mean.

It is our custom, in actual practice, to determine the photographic focus by making a series of exposures, changing the focus by one one-hundredth of an inch between successive exposures. We determined the focus one evening recently by the Hartmann method, using a screen that contained eight holes, and also in the usual way, by making a series of exposures. The focuses determined in these two ways were exactly coincident.

Being curious to know the separating power of the objective, we tried it on some close doubles on a few nights when seeing seemed steady. The components of the closest double that we separated were 0.26″ apart. But we do not regard this as the final word on the separating power of this objective.

From every standpoint the lens is an excellent one. The Hartmann test shows that the focal discrepancies, the diameters of confusion, and T, the weighted diameter of confusion, are all extremely small.

Hartmann's characteristic quantity "T" was computed by his formula

$$T = \frac{100{,}000}{F}\frac{\Sigma rd}{\Sigma r} = \frac{200{,}000\sum_{n=1}^{24} r^2 (A_n - A_o)}{F^2 \Sigma r},$$

where F is the focal length of the objective.

We found:

$T = .068$ from Marriott's measures.

$T = .086$ from Miller's measures.

$T = .070$ from the "resultant" of the measures of Miller and Marriott.

We also, following Fox's[4] suggestion, determined T by making $\Sigma\, rd$ a minimum. The quantity $\Sigma\, rd$ was computed by varying by a few hundredths of a millimetre, the quantity A_0, from that determined by the Hartmann formula and computing the corresponding values of $\Sigma\, rd$.

TABLE III.

1	2	3	4	5	6	7	8
Marriott	A_0	101.55	101.50	101.45	101.41	101.35	101.30
	Σrd	554.71	539.53	521.32	530.50	565.94	606.80
	T	.073	.069	.067	**.068**	.072	.078
Miller	A_0	101.51	101.49	101.45	101.40	101.35	101.30
	Σrd	673.14	667.42	603.39	600.17	607.25	623.24
	T	**.086**	.085	.077	.077	.078	.080
Resultant	A_0	101.50	101.45	101.40	101.35	101.30	101.25
	Σrd	574.48	549.10	547.28	550.07	573.37	603.21
	T	.073	**.070**	.070	.070	.073	.077

The results are exhibited in Table III. The columns 3, 4, 5, 6, 7, and 8 contain the assumed values of A_0, the value of T, and of $\Sigma\, rd$, computed with assumed values of A_0. The value of T, set in bold figures, is obtained by the Hartmann formula.

[4] *Astrophysical Journal*, vol. 27.

Resins in Paleozoic Plants and in Coals of High Rank. D. WHITE. (*U. S. Geol. Survey, Paper* 85 E, 65.)—The supposed absence of resins from the coals of higher rank has led to the view that the coal-forming floras of the Carboniferous period, to which most bituminous and higher-rank coals belong, were destitute of resin-bearing plants, and that these coals have not at any time existed as peats. From a study of petrified fragments of Carboniferous plants, and from observations of Paleozoic coals ("stone-coals"), the author concludes that some of the Carboniferous coal-forming vegetation contained secretions of a resinous nature which became concentrated in the coals, owing to dehydration and the more rapid decay of the other plant tissues. Lump or exudate resins, as well as canal secretions, were found in Paleozoic coals of low bituminous rank. The failure to detect their presence in coals of higher rank is considered to be due to the changes which the resins undergo during the transformation of the coal. These changes, as shown in the coals of the Cretaceous and Tertiary periods (usually lignites or brown coals), are a darkening of the color to a smoky brown, followed by blackening, cracking, and shrinking of the lumps, which are later reduced to dark brownish-black, spongy or granular residues and finally to a fine, thin, powdery black scale. The reduction of the resins coincides with rapid deoxygenation of the coal, and occurs when the proportion of fixed carbon in the coal substance is 60 to 65 per cent. The qualities essential to the production of high-grade coke are developed at the same time.

The Paraffin Motor. ANON. (*Times Eng. Suppl.*, x, 48.)—Paraffin motors are suitable for powers of from 20 to 100 horse-power and have been constructed up to 180 horse-power. The power obtained is about 10 per cent. less than with petrol, and the consumption is 0.7 to 0.8 pint of paraffin (specific gravity 0.82) per British horse-power hour. The normal speed varies from 500 to 800 revolutions per minute with the size of the motor, and the motor can be run down to one-fourth the normal speed. Paraffin carburettors, for running a petrol engine with paraffin, are not entirely satisfactory. In the paraffin motor the vaporizer is usually heated by the exhaust gases, and the engine is started on petrol, or the vaporizer is heated up by a blast lamp. A lower compression is used than in petrol motors.

Prevention of Corrosion of Iron and Steel. (*Brit. Pat. 11,966 of 1913.*)—The objects are heated up to about 750° C. and subjected to the action of a rapid stream of dry ammonia gas for about an hour and a half, after which the furnace is allowed to cool slowly and the current of gas slackened off. By this means a protective layer of iron nitride, Fe_2N, is formed. The nitrified iron is stated to be proof against atmospheric oxidation. The patentee is H. Hanemann.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

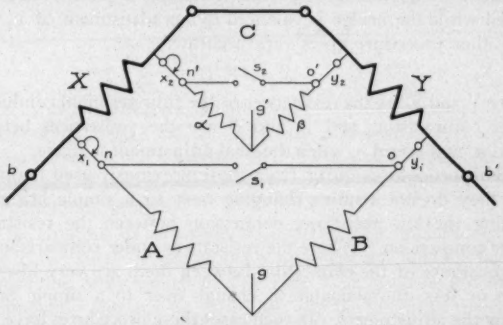
ADJUSTMENTS OF THE THOMSON BRIDGE IN THE MEASUREMENT OF VERY LOW RESISTANCES.†

By F. Wenner and E. Weibel.

[ABSTRACT.]

THE purpose of the paper is to describe two new procedures for carrying out those adjustments which make the correction terms of the Thomson bridge equation negligibly small.

Both procedures require the use of variable double ratio-set so adjusted that for any reading of the dial switches the lack of equality of the two ratios, A/B and α/β (see figure) is so small



that no appreciable error is introduced on this account, and variable low resistances to be used in the connections, x_1 and x_2, between the terminals of the ratio-set and the potential terminals of the four-terminal conductors under comparison.

One of the procedures is as follows:

(1) With the test current supplied through the terminals b and b', the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

* Communicated by the Bureau.

† Scientific Papers of the Bureau of Standards.

(2) With the test current supplied through the terminals n and o, the bridge is balanced by an adjustment of the variable low resistance forming a part of x_1.

(3) With the test current supplied through the terminals n' and o', the bridge is balanced by an adjustment of the variable low resistance forming a part of x_2.

(4) With the test current supplied through the terminals b and b', the bridge is balanced by an adjustment of the dial-switches of the double ratio-set.

In the other procedure the test current is supplied through the terminals b and b' only, but means are provided for connecting the terminals n and o, and n' and o' by conductors of low resistance. The adjustments are made in four steps, of which (1) and (4) are the same as given above. In (2) the terminals n and o are connected while the bridge is balanced by an adjustment of x_1 and in (3) the terminals n' and o' are connected while the bridge is balanced by an adjustment of x_2.

Either procedure gives very accurately

$$X = AY/B$$

where X and Y are the resistances of the four-terminal conductors under comparison; and A and B are the resistances between n and g, and g and o, when the final adjustment is made.

Both procedures differ from those previously used mainly in that they do not require changing over to a simple bridge by opening the low resistance connection between the resistances under comparison. Where the resistances under comparison and the resistance of the connection between them are very low, it is more or less impracticable to change over to a simple bridge during the adjustments. In such cases these procedures have been found more satisfactory.

QUANTITATIVE EXPERIMENTS IN RADIOTELEGRAPHIC TRANSMISSION.*

By L. W. Austin.

THE quantitative study of long-distance radiotelegraphic transmission which was begun by the Navy Department in 1909–10 and described in the Bulletin of the Bureau of Standards, 7,

* Scientific paper to be issued shortly by the Bureau of Standards.

p. 315, 1911, Reprint 159, was again taken up in 1912 in connection with the testing of the high-power radio station at Arlington, Va. This station is equipped with a 100-kilowatt Fessenden rotary gap sending set which gives an antenna current of approximately 100 ampères at a wave-length of 3800 metres. The aërial is triangular in shape and suspended between three steel towers, two of which are 450 feet in height, while the third has a height of 600 feet. The capacity of the antenna is 0.01 microfarad and the height to the centre of capacity 400 feet. Short-range experiments showed that the effective height of the Arlington station was only about one-half the height to the centre of capacity of the antenna. This appears to be generally true of land stations, and is probably due to the fact that they are not erected on sufficiently good conducting surfaces as assumed in the theory. The main scientific object of the experiments was the determination of the correctness of the Sommerfeld transmission formula

$$(1) \qquad I_R = 120\pi \frac{h_1 h_2 I_s}{\lambda dR} \cdot e^{-\frac{0.0019 d}{\sqrt{\lambda}}}$$

where h_1 is the effective height of the sending antenna, h_2 the corresponding height of the receiving antenna, I_s the sending antenna current, λ the wave-length, d the distance between the two stations, and R the effective high-frequency resistance of the receiving antenna system,

The strength of the received signals was measured on the *U. S. S. Birmingham,* which made a voyage to Gibraltar and return for the carrying out of the tests. The total height of the Birmingham's antenna was 130 feet, and the height to the centre of capacity 114 feet. The effective high-frequency resistance was 50 ohms at 3800 metres. Signals were received by means of an electrolytic detector, and their intensity measured by the shunted telephone method which was described in the paper already cited. From the data thus obtained it was possible to determine the received antenna current I_R.

The table shows the results. Column 5 gives the experimental values as obtained from the smoothed curve of observations, and column 3 the values as calculated from the Sommerfeld formula (1). Column 4 gives the calculated values as obtained from a

semi-empirical formula (2) made up of the first term of the theoretical formula, but with the absorption term replaced by the absorption term which was found to be correct in the experiments made in 1910. The values in column 4 are seen to be in very fair agreement with the observed values.

$$(2) \qquad I_R = 120\pi \frac{h_1 h_2 I_s}{\lambda dR} \cdot e^{-\frac{0.0015\, d}{\sqrt{\lambda}}}$$

The Sommerfeld theory takes no account of energy which may be brought to the receiving station by means of reflection or refraction in the upper atmosphere, and it is thought probable that it is this portion of the energy which produces the difference between the observed and theoretical results.

ARLINGTON RECEIVED ON THE "SALEM," FEBRUARY–MARCH, 1913.

Distance		Received current 10^{-4} amp.		
		Calculated		Obs.
Miles	Km.	Eq. 2	Eq. 1	
300	556	335	431	410
400	740	200	278	300
500	925	128	195	225
600	1110	85.2	140	160
800	1480	40.7	79.0	95
1000	1850	20.7	47.6	59
1200	2220	11.0	29.7	34
1500	2780	4.42	15.3	19
2000	3700	1.07	5.65	5.0
2500	4630	0.28	2.20	.....
3000	5560	0.74	0.89	.....

In connection with these experiments a comparison was also made between the received signals from the Fessenden spark set and those from a Poulsen arc temporarily installed at the Arlington station. It was found that, for distances up to about 1000 miles, the received antenna currents were practically the same, for the same sending antenna currents. At greater distances the arc seemed to be superior, as measured on the *Salem* and also at the U. S. naval radio station at Colon, Canal Zone.

VARIOUS MODIFICATIONS OF THERMOPILES HAVING A CONTINUOUS ABSORBING SURFACE.*

By W. W. Coblentz.

In a previous paper (Bulletin Bureau of Standards, No. 188) an account was given of the construction and the behavior of thermopiles composed of bismuth and silver wires with rectangular absorbing surfaces of tin attached to the junctures of these two metals. The novelty of the design consists in a series of overlapping receivers, forming a continuous surface which has all the disadvantages of a good bolometer, with none of the disadvantages of that well-known instrument.

The present paper deals with the construction and the behavior of various modifications of this type of thermo-element, adapted to various problems in biology, physiology, psychology, physics, and astronomy. In the present paper 22 different topics are discussed, and from among the numerous experimental tests a few may be cited.

It was found that by joining the thermo-elements—two in series-parallel—the heat capacity of the composite receiver was reduced and the time to attain temperature equilibrium, after exposing the receiver to radiation, was shortened so that a maximum galvanometer deflection is attained in three to five seconds.

It is shown that the radiation sensitivity of a composite receiving surface is proportional to the square root of the area of the exposed surface. However, this relation does not hold true for the single receivers attached to the individual thermo-junctions. In the latter there is an optimum size of the receiver required to compensate for the loss of heat by conduction along the wires, and by radiation from the surface. Using thermo-elements of bismuth wire 0.1 mm. in diameter, and silver wire 0.036 mm. in diameter, this optimum size of receiver is of the order of 1.5 by 1.5 mm.

In the tests on the relation of external resistance to the internal resistance of the galvanometer it is shown that there may be a considerable departure from equality of the two resistances (the galvanometer resistance may be two to three times the internal [thermopile] resistance) without seriously affecting the efficiency of the galvanometer.

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Tests are given of various samples of bismuth wire, showing that the thermo-electric power against silver varies from 75 to 80 microvolts.

The construction and test of sensitivity of a thermopile of bismuth alloy is given. The alloy was bismuth + 5 per cent. tin. Wires of alloy when joined with pure bismuth wire had a thermo-electric power of 127 microvolts. In spite of this high intrinsic thermo-electric power, the radiation sensitivity of the completed thermopile was not any higher than that of the thermopiles constructed of bismuth and silver, which elements have a 55 per cent. lower thermo-electric power. This is owing to the high resistance of the alloy.

A thermopile constructed of bismuth and iron, which like the aforementioned alloy has a higher thermo-electric power, was no more sensitive than the thermopiles constructed of bismuth and silver. The conclusion arrived at is that the production of a thermopile having a high radiation sensitivity is more dependent upon nicety of construction than upon the use of materials having a high thermo-electric power.

The construction and tests of a radiometer attachment for monochromatic illuminators are given. This device consists of a linear thermopile, which moves in vertical ways in front of the exit slit of a spectroscope. It is useful in measuring the energy value (mechanical equivalent) comprised in the different wave-lengths of light used as stimuli, in biological, chemical, physical, and physiological investigations.

The method of construction and tests are given of a thermopile to be used for absolute measurements of radiation. The device consists of a linear thermopile of bismuth and silver, with a continuous receiving surface, in front of which is situated a strip of manganin or platinum, which is blackened electrolytically with platinum black. This strip of metal is exposed to radiation and in turn radiates to the thermopile, which causes a galvanometer deflection. The strip of metal is then heated electrically to cause a similar deflection of the galvanometer needle; and the power expended gives a measure of the radiation in absolute value. The instrument gives a value of the coefficient of total radiation of a black body which is in excellent agreement with values obtained by other methods.

Among the group of special designs, the stellar thermo-

elements may be mentioned. When used with a reflecting mirror, 92 cm. (36 inches) in diameter, and an ironclad Thomson galvanometer (also described in this paper) of ordinary sensitivity, it was possible to make quantitative measurements of the total radiation from stars down to the 5.3 magnitude, while high qualitative measurements were made on stars down to the seventh magnitude. The application of the thermo-element to solve astronomical problems, therefore, appears to be feasible.

The design and tests are given of an absolute thermopile for the measurement of nocturnal radiation; also of a thermopile to be used as a photometer to measure the blackness of star images on photographic plates. A novel design for a special biological problem consisted in the construction and testing of a linear thermopile, in which the receiver was bent into a U-shaped trough. The test showed that if the object (say muscle or nerve) evolved heat at the rate of 1×10^{-9} g – cal. sec.$^{-1}$ it can be detected.

The appendix consists of notes on (1) galvanometer mirrors, (2) vacuum galvanometers, (3) the most efficient combination of thermopile and galvanometer resistance, and (4) the maintenance of high vacua by means of metallic calcium. The calcium is contained in a quartz-glass tube which is attached to the vacuum (stellar) thermopile. The thermopile container is exhausted by means of an oil pump, and the stopcock is closed. Thereafter the vapors given off are removed by heating the metallic calcium with an alcohol lamp. The device is thoroughly reliable, as evidenced by the fact that it was carried to the Lick Observatory, Mt. Hamilton, Calif., and back, the vacuum having been maintained for over two months with no signs of failure of the calcium.

MEASUREMENTS ON STANDARDS OF RADIATION IN ABSOLUTE VALUE.*

By W. W. Coblentz.

One of the chief needs in the measurement of radiant energy is a convenient standard against which the radiometer may be calibrated. The great utility of a seasoned carbon incandescent lamp as a photometric standard is well recognized, and such a

* Scientific Papers of the Bureau of Standards.

lamp has every desideratum of a standard of radiation, when calibrated against a black body, as the primary standard of radiation. The object of the present investigation is to establish and maintain a standard of radiation in the form of seasoned incandescent lamps, and to issue to experimenters similar standards of radiation, whereby may be obtained an accurate calibration of their radiometers in absolute value.

The incandescent lamps were standardized by two independent methods which are in agreement within 0.5 per cent. The first method consisted in comparing the radiation from a black body with the radiation from the incandescent lamp, assuming a value for the coefficient (the "Stefan-Boltzmann constant") of total radiation of the black body. For this purpose a thermopile was directed towards the black body, then towards the incandescent lamp. The second method consisted in a direct measurement, in absolute value, of the energy of the incandescent lamp with a modified form of Ångström pyrheliometer. This pyrheliometer gave a value ($\sigma = 5.61 \times 10^{-12}$ watt cm^{-2} deg^{-4}) for the coefficient of total radiation which is close to the value of this constant as determined by various other methods differing widely in character.

The standard of radiation, in terms of these incandescent lamps, may therefore be considered fairly well established—at least, sufficient to fulfil present requirements. In the lamps issued to the public the intensity of the radiant energy per $mm.^{-2}$ at a distance of 2 m. from the lamp is certified, when the lamp is operated on a given current and voltage.

For rough calibrations of radiometers in absolute measure a sperm candle of a Hefner lamp may be used. For the sperm candle, burning at a mean height, the intensity of the total radiation at a distance of 1 m. from the flame may be taken to be 29×10^{-6} g – cal per cm^2 per sec. The intensity of the total radiation at a distance of 1 m. from the Hefner lamp *without a diaphragm* may be taken to be 26×10^{-10} g – cal per cm^{-2} per sec. The paper gives data also for the radiation from the Hefner lamp with a diaphragm, having a definite opening, and situated at a definite distance in front of the lamp. The flame standards are unsteady, and various reasons are given for discouraging their use in refined radiation measurements.

A DIRECT READING INSTRUMENT FOR MEASURING THE LOGARITHMIC DECREMENT AND WAVE-LENGTH OF ELECTROMAGNETIC WAVES.*

By Frederick A. Kolster.

[ABSTRACT.]

The paper describes a new instrument for facilitating the measurement of the logarithmic decrement and wave-length of high-frequency oscillations such as exist in the wave trains emitted from radio transmitting stations. The complete theory and design of the instrument are given, as well as experimental data. The measurement of the logarithmic decrement at radio stations is of particular importance, since the United States laws governing radio communication specify, among other things, that the logarithmic decrement per complete oscillation in the wave train emitted by the transmitter shall not exceed two-tenths.

When persistent oscillations of single frequency are emitted from a radio transmitting station much more selective receiving apparatus may be employed with advantage at receiving stations, permitting sharp tuning with consequent minimizing of interference caused by stations other than those with which communication is desired. It is desirable, therefore, that the logarithmic decrement, which is a measure of the decay of a train of waves, be as small as possible.

The instrument described operates in accordance with the method of Bjerknes, but the task of making careful observations and necessary calculations required by the Bjerknes formula is eliminated.

An important element of the instrument is a variable condenser, the capacity of which varies in accordance with the law of geometric progression.

The simplified Bjerknes formula may be written as

$$\delta_1 + \delta_2 = \pi \frac{C_r - C}{C} = \pi \frac{\Delta C}{C}$$

where δ_1 is the decrement of the circuit to be measured, and δ_2 the known decrement of the measuring instrument. C_r is the value

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of capacity of the variable condenser at the point of resonance, and C is a slightly different capacity of such a value that the energy in the instrument at resonance is reduced to one-half.

Since the variable condenser in the instrument varies in accordance with the law of geometric progression, then for any given displacement of the condenser plates the percentage change of capacity $\frac{\Delta C}{C}$ will be constant throughout the range of motion of the condenser. It is therefore possible to attach to this condenser an accurately divided scale from which values of $\delta_1 + \delta_2$ can be read directly.

The methods used for the determination of δ_2, the decrement of the instrument, are discussed and experimental data indicating the accuracy with which measurements of logarithmic decrements can be made are given. Several instruments have been constructed for the Army and Navy and for the radio inspection service of the Department of Commerce.

EQUILIBRIUM IN THE SYSTEM, LEAD ACETATE, LEAD OXIDE, WATER.*

By R. F. Jackson.

IN order to obtain a firm basis for investigating the clarification of raw sugar, a study has been made of the basic acetates of lead from the standpoint of the Phase Rule. The analysis of the basic lead acetates was performed by measuring the volume of standard acid neutralized by the basic lead and the volume of reagent required for the total precipitation of lead. For precipitating lead either sulphuric acid or sodium oxalate was used in excess. In the former case the excess was measured by precipitation with barium chloride, in the latter by titration with potassium permanganate.

The basic acetates were synthesized by the interaction of neutral lead acetate and lead hydroxide. The reaction proceeded very rapidly and produced some striking phenomena. In one instance the reacting substances quickly formed a solution which

* Scientific Papers of the Bureau of Standards.

rapidly solidified to a relatively insoluble crystalline compound. In another case the unmixed components had the appearance of nearly dry solid material, but upon vigorous shaking formed a mobile liquid. The explanation of this is in the formation of a very soluble basic compound. The equilibria were established by at least 48 hours' agitation at constant temperature. The solid phases capable of existence are as follows:

Neutral lead acetate $Pb(C_2H_3O_2)_2 . 3H_2O$ consists of brilliant monoclinic prisms. It is stable in equilibrium with solutions of itself, and its solubility increases very rapidly in solutions of increasing basicity. Its saturation curve is continuous with that extending into acid solutions. The solubility of the neutral acetate in neutral solutions is 35.50 per cent. The extreme basic solution in equilibrium with the neutral acetate contains 15.89 per cent PbO and 48.95 per cent. $Pb(C_2H_3O_2)_2$.

The tetra-lead monoxy hexa-acetate $3Pb(C_2H_3O_2)_2 . PbO . 3H_2O$ crystallizes in needles which are usually minute, but may attain the length of half a centimetre. It is exceedingly soluble in water and forms highly refracting solutions of density 1.93 to 2.28. The solutions contain at the extremes of the saturation curve 15.89 per cent. PbO, 48.95 per cent. $Pb(C_2H_3O_2)_2$, and 24.74 per cent. PbO, 49.21 per cent. $Pb(C_2H_3O_2)_2$. The substance is unstable in contact with solutions of itself, but for its existence in equilibrium with a solution it depends upon an excess of dissolved basic lead. On account of the small size and softness of the crystals and the high density of the mother liquor it is practically impossible to isolate the pure substance.

The tri-lead dioxy diacetate $Pb(C_2H_3O_2)_2 . 2PbO . 4H_2O$ consists of ill-formed needles which may be so small as to seem amorphous. It is capable of existence in contact with solutions of itself, but under such conditions has a solubility of but 13.3 per cent. Its saturation curve, however, possesses a very great length. The extremes of solubility are 7.4 per cent. PbO, 4.8 per cent. $Pb(C_2H_3O_2)_2$, and 24.74 per cent. PbO, 49.21 per cent. $Pb(C_2H_3O_2)_2$.

Lead hydroxide is stable in equilibrium with solutions containing as much as 7.4 per cent. $Pb(C_2H_3O_2)_2$.

A study of the equilibria of the chemical reactions yields an interpretation of the course of the saturation curves.

NATIONAL STANDARD HOSE COUPLINGS AND FITTINGS FOR PUBLIC FIRE SERVICE.*

By P. L. Wormeley.

1. The movement for the adoption of standard fire hose couplings dates from the great Boston fire of 1872, which showed the impossibility of the fire departments of adjacent towns acting in unison when provided with the diverse sizes of hose fittings then prevailing.

2. The matter was taken up at the first Convention of Fire Engineers, in 1873, and was discussed at various conventions in succeeding years. The resolutions gradually became more definite, although little was accomplished toward bringing about the desired changes until the agitation received a new impetus from the Baltimore fire in 1904, when neither the Washington, Philadelphia, nor New York fire engines, on their arrival, could make connection with the local fire hydrants.

3. This condition led the Merchants and Miners Transportation Company, in April, 1904, to request the Secretary of the Department of Commerce and Labor to investigate the subject of fire hose couplings. The Secretary referred the matter to the Bureau of Standards, and, in the investigation which followed, it was found that there was a great diversity in sizes and threads of couplings throughout the United States. It was evident that considerable expense would be involved in changing from one standard to another, and therefore, at the conference of the committees of the National Fire Protection Association and American Water Works Association, held in New York City, April 24, 1905, the Bureau of Standards proposed the adoption either of the thread which could be shown to be most extensively used, or that thread which possessed the greatest advantages in other respects. Following the latter course, the conference resolved that $7\frac{1}{2}$ threads per inch should be recommended for $2\frac{1}{2}$-inch fire hose couplings. This thread was not regarded as an ideal standard, but was considered the most practicable basis for unification under prevailing conditions.

4. At the annual convention of the International Association of Fire Engineers, at Duluth, in 1905, this standard was adopted after lengthy discussion, and at Dallas, in 1906, the convention reaffirmed the action taken at Duluth, and made its record complete

* Abstract of Circular No. 50.

by adopting the National Standard Specifications covering couplings of 3 and 3½ inches inside diameter, each to have 6 threads to the inch, and a 4½-inch coupling having 4 threads to the inch.

5. Since then a dozen large organizations have adopted the national standard. The report of the committee of the American Society of Mechanical Engineers, adopted December 3, 1913, treats its present status in a very clear and comprehensive manner, with suggestions for converting non-standard couplings for serviceable interchange with the national standard. Up to 1913 the national standard had been put into service in 73 cities or towns, either as new equipment or by adaptation of non-standard couplings to interchange with the standard.

STANDARDIZATION OF NO. 200 CEMENT SIEVES.*

By Rudolph J. Wig and J. C. Pearson.

This paper reports the results of an investigation undertaken for the purpose of developing greater uniformity in fineness determinations of cement as ordinarily made on certified No. 200 sieves.

It has been observed that sieves differed considerably in their indications of fineness, and an attempt was made to establish the range in sieving values of as many sieves previously certified by the Bureau of Standards as could be located. Carefully prepared samples of cement were therefore sent to all laboratories known to possess certified sieves, and with the coöperation of these laboratories results of tests on about 160 sieves were obtained. These results showed a variation of nearly 5 per cent. in the fineness of the standard sample, which was assumed, from the study of the results, to be 77.00 per cent. passing the standard No. 200 sieves.

A study was made of the possible causes of discrepancies in sieves, and it was found that no reliable estimates of sieving values could be made from the ordinary certification measurements, nor from other proposed methods of standardizing, except by actually performing the sieving tests with a sample of known fineness. The most probable explanation for these unaccounted-for discrepancies seems to be in the irregular spacing of the warp wires, which cause a variation of 100 per cent. or more in the size of the sieve openings. This very large variation

* Abstract of Technologic Paper No. 42 of the Bureau of Standards.

in size of openings is found to exist in, and to be characteristic of, all No. 200 sieves. It was therefore concluded that such sieves can only be properly standardized by sieving tests, made in strict accord with the specifications, these tests to be supplemented by a brief microscopic examination of the sieve cloth to insure its general uniformity and good quality.

The standardization of sieves tests involves the maintenance of standard samples of cement or other material of similar granulometric composition. A number of finely ground materials were tested to determine their suitability for sieving tests. It was found that normally burned and well-aged cement was better adapted for this purpose than ground quartz, brick, or marble, these four materials having the highest rating in the tests of eleven different materials.

On the basis of the foregoing results a revised specification for Standard No. 200 sieves will be adopted, and standard samples of cement for tests of sieves will be issued by the Bureau at a nominal price. The fineness of the standard samples will be determined on fundamental standard sieves now set aside, which will be replaced by other more exact standards as opportunity offers. Certificates of sieves will, in the future, report the sieving values of the sieves on standard samples from which approximate "corrections" to the sieves can be obtained. The paper discusses the application and use of these sieve corrections in detail.

From the data obtained in the sieving tests a tolerance of 1 per cent. from the specifications in routine fineness determinations is recommended, although means are now available for reducing the error of check tests and other important determinations to 0.5 per cent. or less.

THE INSULATING PROPERTIES OF SOLID DIELECTRICS.*

By Harvey L. Curtis.

Two properties of dielectrics are considered: (1) The volume resistivity and (2) the surface resistivity. The volume resistivity of a material is the resistance in ohms between two opposite faces of a centimetre cube. The surface resistivity is defined as the resistance between two opposite edges of a centimetre square of the surface film which is deposited upon the material.

* Scientific Papers of the Bureau of Standards.

In measuring the volume resistivity, mercury electrodes were employed in order to make good contact, and a guard-ring was used to prevent any errors on account of surface leakage. The effect of the temperature of the specimen, of the humidity of the surrounding air, and of the magnitude and length of application of the applied voltage were studied. The only one of these which, for ordinary laboratory conditions, affects the order of magnitude of the results is the length of application of the voltage, and this is of importance only if the volume resistivity is greater than 10^{13}. Values of the volume resistivity are given in Table I.

TABLE I.

Volume Resistivity of Solid Dielectrics.

(Materials arranged in order of decreasing resistivity.)

Material	Resistivity ohms-cm.	Material	Resistivity ohms-cm.
Special paraffin.....over	5000 x 10^{15}	Paraffined mahogany.....	40 x 10^{12}
Ceresin.....over	5000 x 10^{15}	Stabalite.....	30 x 10^{12}
Fused quartz.....over	5000 x 10^{15}	Plate glass.....	20 x 10^{12}
Hard rubber.....	1000 x 10^{15}	Hallowax No. 1001.....	20 x 10^{12}
Clear mica.....	200 x 10^{15}	Dielectrite.....	5 x 10^{12}
*Sulphur.....	100 x 10^{15}	Bakelite No. 5199 RGRB .	5 x 10^{12}
*Amberite.....	50 x 10^{15}	Bakelite No. 150.....	4 x 10^{12}
*Rosin.....	50 x 10^{15}	Gummon.....	3 x 10^{12}
*Mica (India ruby slightly stained).....	50 x 10^{15}	Tegit.....	2 x 10^{12}
G. E. No. 55 R.....	40 x 10^{15}	Opal glass.....	1 x 10^{12}
Hallowax No. 5055 B.....	20 x 10^{15}		•
Mica (brown African clear)	20 x 10^{15}	Paraffined poplar.....	500 x 10^{9}
Bakelite L558.....	20 x 10^{15}	Bakelite No. G5200RGR..	400 x 10^{9}
*Electrose No. 8.....	20 x 10^{15}	Paraffined maple.....	300 x 10^{9}
*Parowax (paraffin).....	10 x 10^{15}	Bakelite No. 1.....	200 x 10^{9}
Glyptol.....	10 x 10^{15}	Bakelite No. 190.....	100 x 10^{9}
*Shellac.....	10 x 10^{15}	Italian marble.....	100 x 10^{9}
Kavalier glass.....	8 x 10^{15}	Bakelite micarta.....	50 x 10^{9}
*Insulate No. 2.....	8 x 10^{15}	Bakelite No. G5074.....	40 x 10^{9}
*Sealing wax.....	8 x 10^{15}	Black condensite.....	40 x 10^{9}
*Yellow electrose.....	5 x 10^{15}	Yellow condensite.....	40 x 10^{9}
*Duranoid.....	3 x 10^{15}	Vulcabeston.....	20 x 10^{9}
*Murdock No. 100.....	3 x 10^{15}	White celluloid.....	20 x 10^{9}
*Yellow beeswax.....	2 x 10^{15}	Hard fibre.....	20 x 10^{9}
Khotinsky cement.....	2 x 10^{15}	Black galalith.....	20 x 10^{9}
*G. E. No. 40.....	1 x 10^{15}	Lavite.....	20 x 10^{9}
*G. E. No. 55A.....	1 x 10^{15}	White galalith.....	10 x 10^{9}
*Moulded mica.....	1 x 10^{15}	Hemit.....	10 x 10^{9}
		Red fibre.....	5 x 10^{9}
Unglazed porcelain.....	300 x 10^{12}	Marble, pink Tennessee...	5 x 10^{9}
Redmonite (157,4).....	200 x 10^{12}	Marble, blue Vermont.....	1 x 10^{9}
Black electrose.....	100 x 10^{12}		
Tetrachlornaphthalene....	50 x 10^{12}	Ivory.....	200 x 10^{6}
Mica (India ruby stained).	50 x 10^{12}	Slate.....	100 x 10^{6}
German glass.....	50 x 10^{12}	Bakelite No. 140.....	20 x 10^{6}

*Apparent resistivity taken after the voltage had been applied for fifteen minutes.

Since the surface resistivity depends upon the surface film, any condition which will affect this film will affect the surface resistivity. Upon the surface of all insulators except the waxy materials a film of moisture collects from the surrounding air. The thickness and conductivity of this film depend upon the material of which the insulator is composed and upon the relative humidity of the surrounding air. For some materials the surface resistance at 1 per cent. humidity is 10^{11} times larger than at 95 per cent. humidity, though for the majority of materials the surface resistance does not change by a factor of more than 10^6 under these conditions. Since the change is not uniform, it has been found necessary to construct curves showing the change of surface resistivity with humidity. These curves will be found in the original article.

A WATTHOUR METER METHOD OF TESTING INSTRUMENT TRANSFORMERS.*

By P. G. Agnew.

RATIO and phase-angle measurements of instrument transformers may easily be made by the use of two precisely similar watthour meters, which may be of either the portable type or of the house type, provided the disk has been graduated in 100 divisions. The meters should be adjusted to very nearly the same rate.

The method depends upon the use of a standard transformer whose ratio and phase angle have been determined in some laboratory equipped for the purpose. The standard transformer must have the same nominal range as the one under test.

For voltage transformers an auxiliary current is passed in series through the current coils of the two meters. The voltage coil of each meter is connected to one of the transformers, and readings taken showing the difference in speeds of the meters. The meters are then interchanged and readings again taken. If the meters have been operating at, or very near, unity power factor, the ratio of the transformer under test is easily computed in terms of the ratio of the standard. The formula is

* Scientific Papers of the Bureau of Standards.

$$\frac{R_2-R_1}{R_1}=\tfrac{1}{2}\left(\frac{a_1-a_2}{a_2}+\frac{b_1-b_2}{b_2}\right)$$

where R_1, R_2 = ratios of the transformers.

a_1, a_2 = numbers of turns of meter A when connected to transformers 1 and 2, respectively.

b_1, b_2 = same for meter B.

Similarly the difference in phase angles may be determined by running the meters at low power factor, which may be conveniently done by taking the auxiliary current from one of the other phases of a three-phase source. If the meters are working at the power factor cos θ, current lagging,

$$\tan \alpha_2 = \tan \alpha_1 + \frac{1}{\tan \theta}\left[\frac{a_1-a_2}{2a_1}+\frac{b_1-b_2}{2b_1}-\frac{R_2-R_1}{R_1}\right]$$

where the α's are the phase angles of the transformers, counted as positive for the reversed secondary voltage leading the primary voltage.

For current transformers the method of connecting the coils is inverted, compared with the case of the voltage transformer. An auxiliary voltage is applied to the voltage coils of the meters in parallel, the current coils being connected alternately to the two transformers. Care should be taken not to open the secondary circuit of a current transformer while current is passing in the primary. The formula for the difference in ratios is the same as for the voltage transformer. The formula for phase angle is correct as given both for the voltage transformer with lagging current and for the current transformer with leading current. If the conditions are *vice versa*, the + sign before the bracketed term should be changed to −.

It is, however, not necessary to depend upon this equation for determining which transformer has the greater phase angle. The following facts may be used as criteria for experimentally determining the question:

1. Adding a non-inductive load to a voltage transformer always tends to lag the secondary voltage.

2. Increasing the resistance in the secondary of a current transformer tends to advance the phase of the secondary current.

The experimental results show that by taking runs of approximately 100 turns each the method is capable of determining ratio to 0.02 per cent. or 0.03 per cent., and phase angle to one

or two minutes. In commercial work shorter runs would suffice. Results as good as this were also obtained with the speed of the meter doubled by shunting the magnets. Separate direct experiments showed that the modern induction meter, even with the drag magnets shunted so as to give double speed for normal torque, will repeat in consecutive runs under constant conditions to a precision of about 0.01 per cent. at full load.

There are cases in which it may be convenient to determine a lump correction for both ratio and phase angle instead of determining and correcting for them separately; for example, the case of a watthour meter and a current transformer metering the power supplied to an inductive load. This may even be extended to the case of the combination of a current and a voltage transformer.

Portable watthour meters are more convenient than the house type with graduated disks, as the trouble of counting is eliminated. In testing current transformers a five-ampère range is more economical of time than a ten-ampère range. One-ampère or two-ampère ranges should not be used with current transformers, as the impedance introduced into the secondary is too great.

It is important that the constants of the standard transformer should have been tested under actual working conditions of load, including the meter.

The accuracy of the method is ample for commercial requirements, the results are independent of ordinary line fluctuations, and no special apparatus is required.

Note on a Theory of Thunderstorms. H. Nagaoka. (*Mathematico-Physical Soc., Tokyo, Proc.*, vii, 228.)—It is considered that the phenomenon of repeated discharges can be accounted for from the point of view that the thunderclouds form a composite dielectric. The dielectric contains clouds, ions, and air, and the charges are embedded in it. The charges accumulate, the electric field increases in strength, and the wandering of the ions and distribution of cloud particles become favorable for causing a discharge through the intervening layer. Such a composite dielectric will exhibit electric absorption and residual discharge. Further, the disruptive discharge causes the fresh production of ions. The sudden change of pressure in the path of the discharge will sometimes be quite favorable to the condensation of water particles on electrified nuclei. The phenomenon of repeated discharges is, on this account, a natural consequence of electric absorption in cloud masses.

THE FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 2, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 2, 1914.

MR. J. A. P. CRISFIELD, *Chairman pro tem.*

The following report was presented for first reading:

No. 2605.—Blonck Boiler Efficiency Meter.

The following report was presented for final action:

No. 2597.—George A. Wheeler's Escalator. John Scott Legacy Medal and Premium recommendation adopted.

The following report was reconsidered:

No. 2524.—Sperry's Gyro-Compass. John Scott Legacy Medal and Premium recommendation confirmed.

Amendments to the 1913 Regulations were considered and adopted in their final form.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, September 9, 1914.)

RESIDENT.

MR. GEORGE H. BENZON, JR., 252 Mather Road, Jenkintown Pa.

MR. JOSEPH A. JANNEY, JR., Chestnut Hill, Philadelphia, Pa.

MR. GEORGE C. THOMAS, JR., Chestnut Hill, Philadelphia, Pa.

MR. FRANCIS RAWLE WADLEIGH, 20 South Twenty-first Street, Philadelphia, Pa.

MR. CHARLES H. ZIEGLER, 25 Hancock Street, Riverside, N. J.

NON-RESIDENT.

MR. WEBB L. GIBBS, 7717 Coles Avenue, Chicago, Ill.

MR. W. S. RUGG, Westinghouse Electric and Manufacturing Company, 165 Broadway, New York, N. Y.

MR. H. N. SPICER, Room 1926, 30 Church Street, New York, N. Y.

Changes of Address.

MR. M. D. BURKE, Room 706 Second National Bank Building, southeast corner Ninth and Main Streets, Cincinnati, Ohio.

PROF. JAMES BARNES, Care of Brown, Shipley and Company, 123 Pall Mall, London, England.
DR. ELMER L. CORTHELL, North Egremont, Mass.
MR. JAMES DONALD, 17 Victoria Street, London, S. W., England.
MR. BYRON E. ELDRED, 18 East Forty-first Street, New York, N. Y.
MR. WILLIAM C. FARNUM, 3 Central Street, Winchendon, Mass.
MISS EMILY E. HOWSON, Glen Moore, Chester County, Pa.
MR. GEORGE MCCALL, 1106 Spruce Street, Philadephia, Pa.
MR. GEORGE MACLEAN, Room, 1613, 220 West Forty-second Street, New York, N. Y.
MR. PARKE D. MASSEY, Hotel Tivoli, Ancon, Canal Zone, R. de Panama.
MR. THOMAS E. MURRAY, Irving Place and Fifteenth Street, New York, N. Y.
MR. FREDERICK J. PEARSON, Station M, 644 East Forty-first Street, Chicago, Ill.
MR. AUGUSTUS SMITH, R. F. D. No. 2, Elizabeth, N. J.
MR. HORACE B. SMITH, 2229 Chelsea Avenue, Walbrook, Baltimore, Md.
MR. HARRISON D. STRATTON, 3837 Market Street, Philadelphia, Pa.
MR. EDWIN D. TUCKER, Little Silver, N. J.
MR. ARTHUR WILLIAMS, Fifteenth Street and Irving Place, New York, N. Y.
MR. EDWARD WOOLMAN, northeast corner Buck and Panmure Roads, Haverford, Pa.

NECROLOGY.

Mr. Richard Young was born in Philadelphia on February 4, 1836. In middle life he removed to Morton, Pa., where he resided for over forty years. He was greatly interested in the educational work of this and neighboring communities. He was connected with a number of local public service corporations, and was elected to fill municipal offices on several occasions. Mr. Young held membership in prominent organizations. He was elected a life member of the Institute on January 20, 1869. He died at Morton on June 20, 1914.

THE FRANKLIN MEDAL.

SAMUEL INSULL, ESQ., of Chicago, Illinois, writing under date of December 23, 1913, to the Board of Managers, stated that he had been informed it would be a source of gratification to them if the Institute had available, in addition to such medals already in its gift, a medal to be known as The Franklin Medal, and to be awarded from time to time in recognition of the total contributions of individuals to science or to the applications of physical science to industry, rather than in recognition of any single invention or discovery, however important. He agreed to provide for the founding of this medal under the following general conditions:

1. That an amount not exceeding one thousand dollars should be furnished by him for procuring appropriate designs and dies for the medal and diploma.

2. That the medal should possess distinct artistic merit, and have on one

THE FRANKLIN MEDAL

FOUNDED JANUARY 1st, 1914, BY SAMUEL INSULL, ESQ.

Modelled by R Tait McKenzie, Sculptor.

Obverse

Reverse

EXACT SIZE

OBERLIN
COLLEGE
LIBRARY.

side a medallion of Benjamin Franklin done from the Thomas Sully portrait in the possession of the Institute.

3. That the medal should be of gold and have an intrinsic value of about seventy-five dollars.

4. That the sum of five thousand dollars should be provided by him to be held in trust in perpetuity to be a foundation for this medal, and to be known as the Franklin Medal Fund (Founded January 1, 1914, by Samuel Insull, Esq.).

5. That the interest of this fund should be used from time to time in awarding The Franklin Medal to those workers in physical science or technology, without regard to country, whose efforts have, in the judgment of the Institute, done most to advance a knowledge of physical science or its applications.

6. That any excess of income from this fund, beyond such average annual sum as might be deemed necessary by the Institute for the number of medals it is considered best to award, might be used for premiums to accompany the medals.

Mr. Insull said he understood that the Institute would be glad to award, on the average, two Franklin Medals a year. Though this would leave little surplus, he inserted the sixth condition to prevent an undesirable accumulation of the fund.

AT THE STATED MEETING of the Board of Managers, February 11, 1914, the above offer was accepted, and its acceptance was confirmed to Mr. Insull in the following resolutions:

"*Resolved*, That the Board of Managers of The Franklin Institute of the State of Pennsylvania accept the offer of Mr. Samuel Insull to establish The Franklin Medal, under the conditions named in his letter of December 23, 1913.

"*Resolved* further, that it is the sense of the Board of Managers of The Franklin Institute that Mr. Insull, in founding this Medal, has rendered a notable service in stimulating workers in Physical Science and Technology and has extended materially the useful activities of the Institute.

"*Resolved* further, that the thanks of the Board of Managers of the Institute be, and are hereby, extended to Mr. Insull for his generous and greatly appreciated action.

"*Resolved* further, that an engrossed copy of these resolutions be forwarded to Mr. Insull."

ON MARCH 24, 1914, Mr. Insull forwarded his check for six thousand dollars, and the following deed was duly executed and delivered:

KNOW ALL MEN BY THESE PRESENTS, That THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA FOR THE PROMOTION OF THE MECHANIC ARTS, hereinafter named The Franklin Institute, for and in consideration of the sum of Six Thousand ($6,000) Dollars to it in hand paid by Samuel Insull, Esq., the receipt whereof is hereby acknowledged, does hereby certify and declare that it holds and will use said sum of money for the following uses, intents and purposes, and upon the following perpetual trusts, that is to say:

1. To expend One Thousand ($1,000) Dollars, or so much thereof as may be necessary, for the purpose of paying for the design of a medal, and the necessary dies and diploma plates for the purposes hereinafter set forth.

2. To invest and keep invested the balance of said sum, and from the income derived from such investments from time to time to strike off and award medals from said design to workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Board of Managers of said The Franklin Institute have done most to advance our knowledge of physical science or its application. Should the income derived from this fund be more than necessary for the purpose aforesaid, the said The Franklin Institute may, in its discretion, award so much of the surplus, as its Board of Managers deems wise, as premiums to accompany said medals.

3. The fund thus set apart shall be known as "The Franklin Medal Fund" (Founded January 1, 1914, by Samuel Insull, Esq.).

4. The medals to be awarded, as aforesaid, shall be of gold, shall have distinct artistic merit, shall be of the intrinsic value of about seventy-five ($75) dollars, and shall have on one side thereof a medallion of Benjamin Franklin taken from his portrait by Thomas Sully, now in the possession of the said The Franklin Institute.

IN WITNESS WHEREOF, The said The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts has hereunto set its common corporate seal, attested by the signatures of its President and Secretary, this 28th day of March, A. D. 1914.

[SEAL]

WALTON CLARK,
President.
R. B. OWENS,
Secretary.

CORRESPONDENCE.

NATIONAL ELECTRIC LIGHT ASSOCIATION,
NEW YORK, July 17, 1914.

WALTON CLARK, ESQ.,
The Franklin Institute, Philadelphia, Pa.

DEAR SIR:—

I have much pleasure in forwarding you herewith copy of a resolution adopted at our recent annual convention in Philadelphia.*

Yours truly,
(Signed) T. C. MARTIN,
Secretary.

WHEREAS, Thirty years ago The Franklin Institute, with courage and foresight, organized the First International Electrical Exhibition and the First International Electrical Congress in this country, thereby giving an enormous stimulus to the electrical sciences; and

* Thirty-seventh Convention, held June 1, 2, 3, 4, 5, 1914.

WHEREAS, At this convention it has coöperated to signalize this thirtieth anniversary:

Resolved, That the thanks of the Association be tendered to the Institute for its brilliant coöperation, for the loan and exhibition at the Public Policy meeting of precious Franklin relics; and

Resolved, That the thanks of the Association be most warmly extended to the Institute, to President Walton Clark, and to Dr. R. B. Owens, Secretary.

(Signed) T. C. MARTIN, *Secretary*

(Signed) JOS. B. MCCALL, *President.*

CORRECTION.

IN the article "The Present Status of Airships in Europe," by Jerome C. Hunsaker, June, 1914, issue, Figs. 4, 5, 6, 7, 17, and 18 should have been credited to "Jahrbuch der Luftfahrt" and "Zeitschrift für Flugtechnik und Motorluftschiffahrt," edited and published in Munich, Bavaria, by Ansbert Vorreiter.

LIBRARY NOTES.

Purchases.

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City Club of Chicago, Through Routes for Chicago's Steam Railroads. Chicago, 1914. (From the Club.)

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BOOK NOTICES.

A POPULAR TREATISE ON THE COLLOIDS IN THE INDUSTRIAL ARTS. By Professor Dr. Kurt Arndt. Translated by Nahum E. Katz, B.Sc. Small 8vo, 60 pages and index. The Chemical Publishing Company, Easton, Pa. Price 75 cents.

The author's preface tells us that the book is based on a lecture delivered before a Berlin society, and is intended to present the popular rather than the highly scientific phases of the applied chemistry of colloids. The translator states that the text is from the second German edition and has been supplied with an index, which (we are not astonished to learn) was missing from the original.

The first part of the book, devoted to explanations of terms, gives in simple language the basic facts concerning this comparatively new but actively exploited department of physical chemistry. The ability of the author is a guarantee that the statements are correct. The several topics are well chosen and interestingly treated. The translation is well done, but falls off a little in the later pages. It seems to the reviewer that original German terms are needlessly introduced. Thus the term "reversible" is well established in its technical sense in physical chemistry; it is not necessary to insert after it—in parenthesis—"umkehrbar."

The work is neatly and clearly printed and will be a useful addition to the literature on the subject.

HENRY LEFFMANN.

PRACTICAL IRON FOUNDING. By Joseph G. Horner, A. M. I. Mech. E. Fourth Edition, thoroughly revised and enlarged. London and New York, Whitaker Company, 1914. 409 pages, illustrations, plates, 12mo. Price 5 shillings.

Since the first edition of this little text-book was issued the art of the iron founder has been almost revolutionized in all its phases. The most notable advances have occurred in the rapid substitution of moulding machines for hand moulding in recent years, and in the practical knowledge gained of the relation between the physical properties and chemical constitution of cast iron as well as of other metallic alloys used by founders.

The book under review treats of these modern methods in a concise manner easily comprehended by students, apprentices, and young engineers, to whom it will be found especially useful. There are 283 illustrations in the body of the book and 15 tables in the Appendix.

This is one of a series of "Practical Handbooks" published by Whitaker and Company; the typography, paper, and binding are good, and the half-tone illustrations, as well as wood-cuts and zinc etchings, are all very well produced.

In conclusion it may be said that the book will appeal more directly to students and founders in Great Britain than in this country, where many advanced methods have been developed that are not alluded to and are apparently not generally known abroad.

A. E. OUTERBRIDGE, JR.

PUBLICATIONS RECEIVED.

Introduction to Organic Chemistry, by John Tappan Stoddard, Professor of Chemistry in Smith College. 419 pages, 5 x 7 inches. Philadelphia, P. Blakiston's Son and Co., no date. Price $1.50.

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U. S. Department of Agriculture, Bulletin No. 115, Professional Paper, Gate Structures for Irrigation Canals, by Fred C. Scobey, Irrigation Engineer, Irrigation Investigations. 61 pages, illustrations, plates, 8vo. Farmers' Bulletin 602, Production of Clean Milk Prepared in the Dairy Division. 18 pages, illustrations, 8vo. Farmers' Bulletin 605, Sudan Grass as a Forage Crop, by H. N. Vinall, Agronomist, Office of Forage-crop Investigations. 20 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

U. S. Geological Survey, Bulletin 599, Our Mineral Reserves. How to Make America Industrially Independent, by George Otis Smith. 48 pages, 8vo. Washington, Government Printing Office, 1914.

Boron in Mineral Waters. H. FONZES-DIACON and FABRE. (*Comptes Rend.*, clviii, 1541.)—The boron content of various mineral waters was investigated by the colorimetric method of Bertrand and Agulhon. It seems to depend to some extent upon the temperature, varying from 0.05 to 0.07 mgm. per litre for the Royat group, and rather less for the Vichy group, to less than 0.005 mgm. in cold mineral waters.

CURRENT TOPICS

Gran-Annular Electric Furnace. Z. JEFFRIES. (*Metal. and Chem. Engin.*, xii, 154.)—The furnace of C. H. Fulton and W. A. Coursen consists essentially of two concentric tubes, of alundum or magnesia, forming an annular chamber for the granulated resistor, viz., kryptol, carbon of the Carbon Company, or graphite of the Acheson Company. The crucible is stored within the inner tube, of 2 inches diameter. The tubes are imbedded in heavy graphite plates, to which the terminals are attached; outside are powdered magnesia and asbestos. From measurements made in such a furnace with the aid of thermocouples it follows that the three resistor materials mentioned have all a negative temperature coefficient; in the kryptol the resistance dropped from 8.3 ohms to about 1 ohm per cubic inch, as the temperature rose to 1500° C., in the carbon from 5 to 0.5, in the graphite from 1.8 to 0.6; in the last case particularly the small fall of resistance with rising temperature seems to be mainly due to the better contact between the grains consequent upon expansion. The resistance is increased by each heating, owing to the oxidation of some carbon, and the material has to be renewed after about 40 heatings up to 1500° C.

Colloidal Carbon Obtained by a Chemical Method. L. SABBATANI. (*Kolloid-Zeits.*, xiv, 29.)—Two grammes of finely powdered sugar are added, gradually during two hours, to 20 c.c. of concentrated sulphuric acid, with constant agitation, and the mixture is allowed to stand at ordinary temperature. After 24 hours the viscous, deep black liquid is poured gradually, with agitation, into 80 c.c. of water, the solution filtered, and dialyzed until free from sulphuric acid. The clear black solution of colloidal carbon thus obtained is very stable; the colloidal particles have an electronegative charge. Gelatinous carbon is obtained by mixing sugar and acid as described above, shaking for two hours, allowing to stand for three to four days at the ordinary temperature, then pouring into a shallow vessel and leaving it together with a vessel of water under a bell-jar. After seven to nine days the viscous solution is converted into a gelatinous mass, which is freed from acid by immersion in water, which is frequently changed. When withdrawn from the water and exposed to air, the jelly gradually shrinks and loses weight. After drying, it forms a very hard, shiny mass, difficult to pulverize, and showing a conchoidal fracture. It swells slightly in water, and dissolves sparingly in alkalies, yielding a colloidal solution.

Interference of Röntgen Rays and Heat Motion. P. DEBYE. (*Ann. d. Physik*, xliii, 1, 49.)—Gives various calculations relating to the theory which indicates that heat motion in the atoms has an essential influence on the interference phenomena observed with Röntgen radiation. The interference intensity decreases exponentially with respect to heat motion (*a*) with increasing angular distance between incident and observation direction, (*b*) with increasing temperature, (*c*) with decreasing wave-length. The exponent of the exponential function vanishes when $T = 0$ with failing null-point energy, and maintains a finite value when a null-point energy exists. The exponent is inversely proportional to the square of the wave-length. The interference intensity is accompanied by a dissipation intensity which is most intense where the interference intensity appears most feeble, and *vice versa*. The course of the phenomena can be calculated when data are forthcoming on the behavior of the specific heat as function of the temperature. A law of similarity holds as with the specific heats of monatomic bodies, according to which the course of temperature is a function of the relation of the characteristic temperature to the temperature of observation.

Advances in Metallurgy of Iron and Steel. SIR ROBERT HADFIELD. (*Presidential Address, Faraday Soc.*, June 11, 1914.)—This address embraced the following subjects: (1) Early metallurgy and alloys of iron and steel. (2) Ancient iron and the Delhi Pillar. (3) Faraday's experiments in 1882. (4) Early workers in scientific metallurgy. (5) French metallurgy in the eighteenth and nineteenth centuries. (6) Value of research. (7) The author's research work. (8) Metallurgy in the middle of the last century. (9) Steel alloys research. (10) Science and practice working together. (11) Development of research during the last fifty years. (12) Special steel alloys. (13) Effect of carbon upon iron. (14) The author's experiments on alloy tool steel. (15) Tool steel of lower carbon percentage. (16) The great work of Ledebur. (17) Allotropic theory. (18) The author's papers on alloys of iron. (19) Thermal treatment. (20) Low-temperature experiments in Great Britain and America. (21) Field for research. (22) The non-magnetic and magnetic conditions of manganese steel. (23) Melting-points. (24) Microscopy (Sorby's work as the originator of metallography). (25) Percy's work. (26) The art of scientific discovery. (27) Why research work is so valuable. (28) The work of the National Physical Laboratory. (29) Past progress in metallurgy. (30) The scope of the University. (31) The Faraday Society.

Instruments for High-frequency Currents and Voltages. W. H. ECCLES. (*Electrician*, lxxii, 1044.)—A description of a simple hot-wire ammeter of quick period, a very sensitive electrometer of simple construction, and a convection galvanometer. All have been employed successfully by the author for high-frequency work.

Sun-power Plants. ANON. (*Amer Mach.*, xli, No. 7, 270.)—In a paper presented to the Institution of Engineers and Ship-builders, dealing with the commercial utilization of sun-power, it is pointed out that the uses to which sun-power plants can be put are unlimited, but probably from their very nature they will be chiefly used, to begin with, for irrigation purposes. In Egypt alone 100,000 men are employed all the year round in filling watercourses with buckets of water from the Nile. These men will find more useful and profitable scope for their labor, and, as prejudice is gradually dispelled, industries will be started in the tropics that were never even dreamed of. The Nile Valley, rich in everything but nitrates, uses 70,000 tons of artificial fertilizers per annum. Here, then, is a profitable field for cheap power, with the supply and demand in the same place. The manufacture of artificial ice is another industry that suggests itself as being suitable for sun-power, and could there be a more rational source of heat for all evaporators for whatever purpose? The synthetic production of hydrocarbon gas from calcium carbide, which could be produced at small cost in electrical furnaces, using sun plants, gives a means of getting illuminating gas apart from coal.

Canadian Pure Food Regulations. ANON. (*Chem. Trade J.*, June 6, 1914.)—A Canadian Order-in-Council lays down certain regulations made in accordance with the provisions of Section 26 of the Adulteration of Foods Act. The regulations governing the employment of preservatives apply to foods intended for domestic consumption. Foods intended for export may contain certain preservatives, provided that, both in specific character and in amount, such preservatives do not conflict with regulations in force in the country to which export is made.

It is forbidden to add any preservative whatever to milk, or any other than the following to foods especially intended for the use of infants or invalids: Common salt, salpetre, woodsmoke, vinegar, acetic acid, spices, or alcohol. These preservatives, which are included in Class I, may be used without declaration of their presence, provided that such use does not conflict with any other statutory regulation.

Class II refers to preservatives which may be used until further notice, provided that no more than one kind of preservative substance, named in the list, shall be added to any one kind of food, or to any mixture of two or more kinds of food; that the amount of preservative shall not exceed the maximum amount named, and that the presence of the preservative shall be declared on the label.

Toleration of the use of this class of preservative is dependent upon the fact that available evidence concerning their physiological action is not considered sufficient to prove that under the prescribed regulations they are harmful to health in such a degree as to bring them under Section 3 (*f*) of the Adulteration Act, which reads as follows: "Food shall be deemed to be adulterated within the meaning

of this act if it contains any added poisonous ingredient, or any ingredient which may render such an article injurious to the health of the persons or cattle consuming it." Should satisfactory evidence of the harmfulness to health of any of the preservatives named in Class II be forthcoming, such preservatives would immediately fall under the condemnation of the Adulteration Act, and foods containing such preservatives would be declared to be adulterated.

(1) Boric acid (boracic acid) or borax. Limit: 1 part in 400 in cream; 1 part in 200 in butter and other foods. (2) Benzoic acid (sodium benzoate). Limit: 1 part in 1000 parts. (3) Salicylic acid. Limit: 1 part in 5000 parts. (4) Sulphurous acid (sodium, potassium or calcium bisulphites). Limit: 1 part in 10,000 parts in beverages; 1 part in 2000 parts in solid foods. (5) Saccharin. Limit: 1 part in 1500 parts in beverages; 1 part in 700 parts in solid foods. (This substance shall not be used to take the place of sugar in any food in which sugar is employed as a source of nutriment, or for its feeding value. Where sugar is used only as a sweetener, saccharin may replace it under the conditions defined above.)

The following preservative substances, included in Class III, are prohibited from use in foods: Formaldehyde, (formalin), beta-naphthol, abrastol (asaprol), hydrofluoric acid, fluorides, fluo-borates, fluo-silicates, or other fluorine compounds.

New Chemists' Slide Rule. H. R. LEE. (*Metall. and Chem. Engin.*, xii, 201.)—This is a description of a new type of slide rule designed to meet the needs of chemists engaged in commercial analysis. The regular or front side of the rule shows the molecular symbols of forty-six salts and ten acids and bases on the A scale of the frame, and a parallel list of these on the B scale of the slide. On the back appear the symbols of forty-two elements and thirty-seven oxides in place of the usual A scale on the frame, and a parallel list of these on the B1 scale of the slide. The C and D scales on the front and the C1 and D1 scales on the back are graduated numerically, as is usual on the engineers' slide rule. The results obtained with the rule are of as high order of accuracy as the chemical work, which precedes its use, is usually expected to be.

The Corrosion of Aluminum. ANON. (*Metal Ind.*, xii, No. 8, 345.)—Recent researches prove that aluminum is subject to two kinds of corrosion: one resulting from a uniform attack all over the surface, while the other is localized in scales and spots. The second case is generally produced on metal which has been mechanically worked by drawing or rolling. As in the case of iron, it seems that the metal must be exposed to air and moisture at the same time, for one alone will not produce it. Carbonic acid is a leading element in the corrosion. Worked aluminum scales off in the direction in which the mechanical action has been carried out.

Use of Gold in Ceramics. A. GRANGER. (*La Céramique*, 1912, 262, and 1913, 3.)—Gold is used on pottery either for gilding or as a coloring agent in glazes. Its value for gilding lies in its resistance to oxidation and the fineness of the layer which can be produced, for which reason it is not an expensive stain. A flux is employed in application, and mercurous oxide reduces the amount of gold required. A mixing of the composition: 30 parts by weight of precipitated gold, 15 of black mercurous oxide, 2.5 of basic bismuth nitrate, and 0.3 of melted borax, is recommended; the addition of 3 parts of silver carbonate to this produces a greenish tint. After firing in the muffle the gold has a matt surface, and must be polished with bloodstone or agate. A cheaper process, which does not require polishing after the burn, is the use of "Glanzgold" or "Meissengold," a preparation of gold solution with an organic medium such as turpentine, lavender oil, and balsam or resin. As a coloring agent in glazes, gold produces shades from violet to purple and red, of which the best known is purple of Cassius, a lake of precipitated gold with a metallic hydroxide, preferably that of tin, which was formerly regarded as a definite compound. The presence of ammonia or alum in the stannous chloride solution produces shades from dark to rose-purple, and the tint may be further modified by the substitution of antimony or magnesia for tin. Choice of flux materially influences the color; various recipes are given containing lead oxide, borax, or feldspar; and kaolin may be used as a base for the lake. In lead glazes 1 part of gold in 1000 parts of glaze powder will produce a deep red glaze; and in leadless glazes, 1 in 10,000. An under glaze stain can be produced from 50 parts of pegmatite, 50 of alumina, and 1 of gold chloride. Gold may be applied under a glaze on places previously moistened with gum tragacanth solution.

Base-metal Thermocouples. O. L. KOWALKE. (*Amer. Electrochem. Soc. Trans.*, xxiv, 377.)—Investigations were made on various thermocouples which have recently come into use for industrial purposes, and are made of metals, such as iron and nickel and alloys of nickel, cobalt, etc. The object was to determine how the electromotive force of the couples varied with the temperature, and how its constancy was affected by successive heatings and coolings and by exposure to various temperatures for extended periods of time. The couples tested were all compared with a Pt and Pt-Rh couple which had been standardized by a similar couple certified by the Bureau of Standards. From the experiments made it seems possible to obtain a base-metal couple which is reasonably homogeneous and will give indications of temperature which are sufficiently constant to meet the requirements of the industries. For measurements of a greater accuracy than within 25° a higher grade of instrument is required. Sufficient care is not exercised in thoroughly annealing couples. Once the couple has attained its permanent structure there is not much change in the electromotive force.

The Atmospheric Obscurity of 1912–13. J. MAURER and C. DORNO. (*Meteorolog. Zeitschr.*, xxxi, 49.)—At the beginning of 1913 the president of the Radiation Commission of the International Meteorological Committee, J. Maurer, issued a circular letter to meteorological institutes, asking that observational material on the remarkable atmospheric obscurity of 1912 should be sent to him. The paper is a report on the results obtained on working up the material received in response to the letter.

The general cause of the obscurity is attributed to the volcanic eruption of Katmai, in Alaska, on June 6, 1912; for successive phases of obscurity can be traced from place to place in relation to the time which had elapsed since the eruption. The first phase began on June 6 in the form of high, clear clouds which travelled from WNW. to ESE. This phase reached Zürich on June 23rd, Egypt on June 28th, and it was not sufficiently intense to affect the records of Campbell-Stokes sunshine recorders. The maximum intensity of this phase at any place usually occurred at one to three weeks after the commencement. The second phase, which was similar in character to the first, was observed on Mount Wilson on June 21st. It reached Algiers on July 11th and Egypt on August 8th. The third phase was noted in Washington to commence from July 19th to 26th, and it arrived in Egypt at the end of August, but this phase was lacking altogether at some stations, while at others the maximum of disturbance occurred during its course. The fourth phase spread from America to Egypt during the month of September. The end of the disturbance was noted in October at most places. The phenomena appeared to be confined to that part of the northern hemisphere lying between the polar circle and the Tropic of Cancer, but it is not ascertained whether they extended completely round the globe, within those limits.

Copper Production in Russia. ANON. (*The Metal Ind.*, xii, No. 7, 292.)—The production of copper in the Caucasus in 1913 was 9222 tons, as compared with 10,368 tons in 1912. One of the three companies is erecting a concentration plant, part of which was completed and in operation before the end of 1913. A new ropeway was also completed, and other improvements were made. The company hopes to maintain production at 400 to 500 tons per month. A new plant was erected by another firm at its copper deposits at Kvartshana, in the province of Batum, and it is reported that considerable ore there is ready for treatment as soon as the blast furnace smelting works are completed.

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